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Development of Acceptance Plans for Airport Pavement Materials

Vol. I—Development

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16. Abstract

The objective of this research is to develop statistically based acceptance/rejection plans and payment adjustment schedules for five specifications covered under the Federal Aviation Administrations (FAA) Advisory Circular (AC) No. 150/5370/10, Standards for Specifying the Construction of Airports, namely:

P-152, Excavation and Embankment,
P-209, Crushed Aggregate Base Course,
P-304. Cement Treated Base Course,
P-306, Econocrete Subbase Course,
P-501, Portland Cement Concrete Pavement.

Previously, the Pennsylvania State University developed plans for Specification P-401, Plant Mix Bituminous Pavements, which were adopted for use in 1984.

This report includes the statistical analysis of data, development of payment adjustment plans (PAP), and development of PAP computer diskette system. Test data used for this effort were collected from field sources. The developed PAP formulas, schedules, and computer diskette system were verified using new pavement construction projects.

This report is divided into two volumes with Volume I, Development, describing the development of PAP, and Volume II, Computer Operator's Manual, describing the operation details of the PAP diskette system.

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Acceptance Plan, Payment Adjustment Schedules, Airport Pavements, Data Collection, Data Entry, Operating Characteristics Curves.

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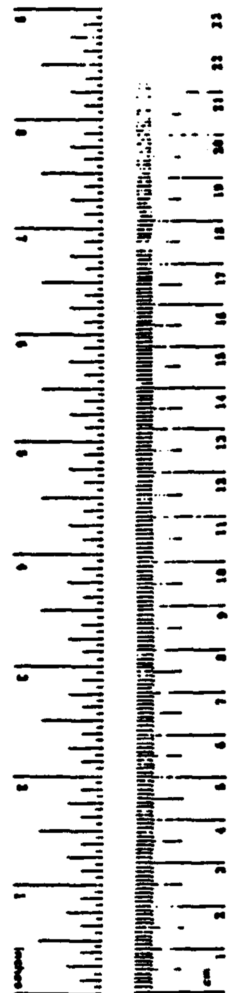
Approximate Conversions to Metric Measures

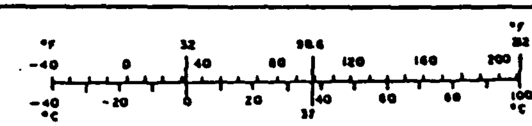
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



METRIC CONVERSION FACTORS

PREFACE

The overall objective of this effort was to develop and test a statistically based acceptance plan and a payment adjustment schedule for five types of airport pavement materials.

The effort was divided into three work elements, with the first being existing pavement test data collection, the second being development of the acceptance and payment adjustment plan, and the third being testing of this plan.

Work Element No. 1 includes a literature search of any published reports of a similar nature, collection of applicable airport pavement test data, and performing a feasibility study of the practicality of having acceptance plans and payment adjustment schedules on certain materials. Important activities of this Work Element are listed in Chapter 2.

Work Element No. 2 includes an organizational analysis of collected data, development of PAP specifications and acceptance control procedures, and incorporation into a computerized program. Details of these activities are listed in Chapters 3 through 6 of this report.

Work Element No. 3 includes a field evaluation of the developed PAP computerized formulation program at airport pavement construction projects and a final fine tune adjustment of the PAP program. Details of these activities are listed in Chapters 7 through 10 of this report.

The study to develop the acceptance plans and payment adjustment schedules was awarded to John E. Foster and Associates, Inc., with Resource International, Inc. providing statistical analysis assistance.

Special acknowledgements to the following for their contribution to this report:

Literature Search and Review: George J. Ilves.
Airport Data Collection: Carl L. Mumford, P.E.
Feasibility Study: Abdulshafi A. Abdulshafi, P.E. and Kamil E. Kaloush, P.E.
Statistical Analysis of Data and Development of Payment Adjustment Plans: Dirk Wiers, James C. Kennedy, Jr. Ph.D., and William V. Harper, Ph.D.
Development of Payment Adjustment Plan (PAP) Diskette System: Carl L. Mumford, P.E.
Field Evaluation of Airport Pavement Construction Projects: Carl L. Mumford, P.E.
Final Adjustment of Payment Adjustment Formulation: James C. Kennedy, Jr. Ph.D.

During the preparation of this report, Dr. Aston McLaughlin was the Technical Officer for the Federal Aviation Administration.

A special thanks to the Federal Aviation Administration offices, airport consultants/engineers, and airport authorities, who provided valuable information and test data. The list is too extensive to include here; however, it is included in Chapter 2, Table 2.4 of this report.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF APPENDIXES

TABLE OF APPENDIXES (continued)

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviations

ANOVA	Analysis of Variance
AQL	Acceptable Quality Limit
BMDP	Biomedical Computer Programs
DBMS	Data Base Management System
DOS	Disk Operating System
$EPAL_m$	Estimated Percentage Above Limit
LTPD	Lot Tolerance Percent Defective
MS-DOS	Microsoft Disk Operating System
OC	Operating Characteristic
PAL	Percentage Above Limit
P-152	P-152, Excavation and Embankment
P-209	P-209, Crushed Aggregate Base Course
P-304	P-304, Cement Treated Base Course
P-306	P-306, Econocrete Subbase Course
P-401	P-401, Bituminous Surface Course
P-501	P-501, Portland Cement Concrete Pavement
PAP	Payment Adjustment Plans
PWL	Percent Within Limits
Q	Quality Index
QC	Quality Control
RQL	Rejection Quality Limit
SAS	Statistical Analysis System
SPSS	Statistical Programs Social Science
TRIS	Transportation Research Information Systems
UMVU	Uniformly Minimum Variance Unbiased
UQL	Unacceptable Quality Limit or (RQL) Rejection Quality Limit

Organizations

AASHTO	American Association of State Highway and Transportation Officials
A/E	Architectural/Engineering
ASCII	American National Standard Code for Information Interchange
ASTM	American Society for Testing and Materials
DIALOG	Information Services, Inc., Palo Alto, CA
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
IBM	International Business Machines Corporation
JEFA	John E. Foster and Associates, Inc.
RII	Resource International, Inc.
TRB	Transportation Research Board
USCE	U.S. Army Corps of Engineers
WES	U.S. Army Corps of Engineers Waterways Experimental Station

LIST OF SYMBOLS

$\bar{x}$		Average (of tests), sample mean
S		Standard Deviation
Q		Quality Index
L		Lower Limit of Material Specification
μ		Population mean
ϵ	$r * \sigma$	units by which the sample mean deviates from the population mean
$1-\delta$		Probability of occurrence
σ		Population standard deviation
n		Sample size
r		real number

1. INTRODUCTION

1.1 Background

In 1978, the Federal Aviation Administration (FAA) revised Item P-501, Portland Cement Concrete Pavement, to reflect research and updated practices in the field of concrete pavement construction. Among the major changes in the FAA specification is the adoption of flexural strength pay penalty factors based upon statistical concepts. Similarly, in 1981, the FAA adopted Item P-304, Cement-Treated Base Course, to include the field density as a criterion for its pay adjustment schedule.

Specifications for P-152, Excavation and Embankment, and P-209, Crushed Aggregate Base Course, have not been revised to include quality control criteria and pay penalty factors. Current FAA specifications for these items are based on acceptance/rejection density such that a minimum level of compaction must be achieved. P-306, Econocrete Subbase Course, was adopted in 1981, but has found little usage in the FAA Eastern Region.

Based on a need in the FAA Eastern Region, a payment adjustment schedule has been developed by the FAA for mat and joint densities, as well as for air voids in P-401 Bituminous Surface Course construction. This development was based on a statistical approach which evaluated test results from several airport construction sites in the FAA Eastern Region. The original approach was generated for the FAA by Pennsylvania State University and later field tested by Clemson University under two successive contracts.[5,6,7]

In September 1986, John E. Foster and Associates, Inc., was retained by the FAA to study the possibility of, and to develop, acceptance/rejection plans and payment adjustment schedules for the following specifications included in the FAA Advisory Circular (AC) No. 150/5370-10, Standards for Specifying the Construction of Airports:

- P-152, Excavation and Embankment.
- P-209, Crushed Aggregate Base Course.
- P-304, Cement Treated Base Course.
- P-306, Econocrete Subbase Course.
- P-501, Portland Cement Concrete Pavement.

This research study entitled "Development of Statistically Based Acceptance/Rejection Plans and Payment Adjustment Schedules for Airport Pavement Materials" was divided into three (3) major work elements.

These work elements were as follows:

No. 1 Literature Review, Data Collection, and Feasibility Study.

No. 2 Develop Statistical Payment Adjustment Schedules.

No. 3 Field Testing of Payment Adjustment Schedule on Three (3) Construction Projects.

This Final Report summarizes work performed during Work Element Numbers 2 and 3, and contains important excerpts from Work Element No. 1 listed in Chapter 2.

1.2 Objectives

The overall objective of this effort were to develop a statistically based acceptance plan and a follow-up payment adjustment schedule applicable for specification densities, thicknesses, and/or strengths for the above listed five types of airport pavement materials. The methodology for this plan had previously been developed for the FAA and was utilized to apply to these new materials.

The objectives of Work Element No. 1 were to conduct a "Literature Search" from the appropriate technical documentation, conduct personal interviews, and collect and analyze airport pavement construction test data within the FAA Eastern Region. This effort included a "Feasibility Analysis" concerning the desirability of, and the best means of, assessing adjustments on all selected materials, except for P-501.

The objective of Work Element No. 2 was to utilize the airport pavement construction test data collected during Work Element No. 1 to calculate percentage factors which was to be a basis for the development of tabular payment adjustment schedules. The methodology used, and the computer simulations generated, during these exercises were similar to and compatible with those previously developed for the FAA by Pennsylvania State University and Clemson University on the P-401 material specifications.

Work Element No. 3 applied this developed payment adjustment schedule to three (3) construction projects to verify its application and refine the payment adjustment schedule.

Resource International, Inc. assisted John E. Foster and Associates, Inc. as a subcontractor, providing statistical analysis.

2. LITERATURE SEARCH, DATA COLLECTION, AND FEASIBILITY STUDY

2.1 Literature Search

A detailed review of existing literature was undertaken at the start of this study to:

- o Identify procedures and methods that exist, and can be used in statistical specification development.
- o Evaluate the applicability of various methods for determining pay adjustment plans.
- o Locate any published sources of data that could be used to supplement the data to be collected from the field.

Twenty-four sources of published information were obtained and reviewed to identify methods that had potential application to developing statistical curves and payment adjustment schedules for this study. In addition, unpublished work developed by William DeGraaff, Pavement Engineer, FAA Eastern Region Airports Division Office, relating to the P-401 and P-501 specifications were reviewed.

Of primary interest during the literature review was the question of how pay adjustment schedules (equations or tables) are derived, along with locating potential sources of test data for specifications considered by this study.

The general conclusions of the literature review on the subjects mentioned are:

- o Individual material quality test data are not reported in the literature that is generally available to the public, nor are data readily available from the airport operators/managers.
- o Test data are generally reported to the airport managers in the form of letter reports and these are generally not available without site and/or contractor visits.
- o The concepts used in statistical specification development are discussed in detail by several authors; the most notable of these are Weed, Willenbrock, Kopac, and Burati. There is general agreement that PAL methods and operating characteristic curves should be used. It is also proposed to follow these procedures in this study.
- o Very little guidance is offered for developing pay adjustment schedules for materials where lack of compliance effects cannot readily be determined from mechanistic design considerations.

- Detailed statistical analysis of the test data was required for determining reasonable levels for pay factors which incorporate variabilities due to testing methods, in addition to within lot and among lot variabilities, as well as between contractor variabilities. The methods discussed by Burati and Siddiqui will be used in this study.

The following recommendations are made as a result of the literature review:

- The PAL concept based on standard deviation should be used in developing operating characteristic curves.

- Pay adjustment schedules should be developed based on detailed statistical analysis of quality control test data as well as engineering judgement.

- Operating characteristic curves should be used in developing expected payment schedules.

- Bonus payment plans should be considered to make payment schedules more receptive to the contractor.

- The reasonableness of the combined payment schedule, based on various combinations of individual factors, should be investigated rather than relying on the procedures outlined by Burati or Weed.

2.2 Airport Data Collection

A vital activity of this study was collecting, assembling, editing, and entering airport pavement test data in an organized and accurate data base. This data base would provide the necessary information to perform statistical analysis during the Development of Statistical Payment Adjustment Schedules, Task D.

The test data collection phase consisted of several tasks including a search for published test data, establishing criteria for the airport data sources, establishing type and quantities of test data required, securing test data from possible sources, and sorting and entering the test data into a computer data base. The main focus on the data collection during Work Element No. 1 was confined to the seven (7) states of the FAA Eastern Region, which includes New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and West Virginia, and the District of Columbia. Data were obtained on 146 projects from 27 sources and cover 52 airports.

The majority of airports within the FAA Eastern Region are constructed with P-401, Bituminous Surface Course Pavement, more frequently than P-501, Portland Cement Concrete Pavement. P-304, Cement Treated Base Course, and P-306, Econocrete Subbase Course, are rarely used in construction in the FAA Eastern Region.

The literature search indicated very little published data was available, and that the needed quality control data would have to be collected from the field. Consequently, the original approach to the statistical data collection plan was revised. The revised plan was developed to secure, from the FAA District Offices, lists of airports that had pavement construction within the last ten years. Upon contacting the airport authorities, it was learned that they rarely had any test data available at the central office and referrals were made to their engineering consultants, where the majority of the test data was located.

Concurrently, while searching for published airport pavement construction test data, the five (5) specifications were reviewed and a collection Survey Information form was developed to assist the survey teams' interviews with the airport staff.

Meetings were held with the FAA Eastern Region Airports Division administrators and engineers in the four FAA Airport District Offices. They provided documentation on payment adjustment schedules that have not been published. A list of projects and sources of data were identified, with their assistance, and contacts were made with 45 airport staff and consultants in the seven state area of the Eastern Region. Overall, five (5) meetings were held with FAA offices and 31 meetings with airport staff and consultants. Refer to Table 2.1 for a list of these meetings.

The test data received were screened and analyzed for completeness, quantity, and quality, and compared to the airport selection criteria. It was then entered into a computer data base to be used for statistical analysis.

The original screening criteria established for acceptance/-rejection of test data sets were as follows:

- o Data to be from an Eastern Region airport.
- o Data to be for one of the five (5) specifications required for this effort.
- o Data must have at least 20 test points.
- o The contractor must be a "Competent contractor".
- o Any data "too perfect" or with abnormalities is to be rejected.

Additional criteria were established by the FAA as follows:

- o Use sand-cone test data only; no nuclear test data to be included.
- o Use flexural strength tests and thickness for Item P-501.
- o Data can be collected from nearby regions, if there are insufficient data within the Eastern Region. All data for a specification item must be collected from the same region.

While reviewing the test data for conformity with the required screening criteria, some problems were discovered as follows:

- o Very little test data contained the exact type of material specification that the test was performed on. The data had to be reviewed for pertinent information to indicate the material specification; sometimes there was still insufficient information to properly identify the material.
- o Some data sheets did not include the airport name or its location.
- o Some data sheets contained two different specification items on the same sheet, without specifying the difference between the two types of material.
- o Some Item P-501 test sheets did not indicate if the data were for pavements, foundations, or other structures.
- o Pavement tests below acceptable standards without apparent retesting or documentation of passing tests at the same location were frequent.
- o Some test sheets were disorganized and required considerable sorting of information to arrange into a usable and understandable form.

During the data entry phase, most data were transferred, rearranged, and edited from the test data sheets to the Survey Information forms, because of inconsistent test data sheets and lack of information. Refer to Tables 2.2, 2.3 and 2.4.

In order to make the effort manageable, the dBASE III data base computer program was selected for data entry operation. The software has superior data manipulation features that can be used during the statistical calculation phase of this study.

The total number of projects that were entered into the computer data base and appeared to be valid and usable were as follows:

P-152	Excavation and Embankment (Sand cone data).	26 Projects
P-209	Crushed Aggregate Base Course	
	(Sand cone data).........................	21 Projects
P-304	Cement Treated Base Course.................	05 Projects
P-306	Econocrete Subbase Course	
	Compressive Strength Data................	05 Projects
	Thickness Data...........................	01 Project
P-501	Portland Cement Concrete Pavement	
	Flexural Strength Data...................	18 Projects
	Thickness Data...........................	03 Projects

Screening the data for acceptable statistical analysis eliminated a large amount of collected data and resulted in the following acceptable data:

- Item P-152, Excavation and Embankment: Data were collected on 57 projects; however, eliminating nuclear test data resulted in 26 projects and was sufficient to perform statistical analysis.

- Item P-209, Crushed Aggregate Base Course: Data were collected on 40 projects; however, eliminating nuclear test data resulted in 21 projects, which was sufficient to preform statistical analysis.

- Item P-304, Cement Treated Base Course: Data were collected on five projects tested by the sand cone method. Cement Treated Base Course has very limited application in the Eastern Region.

- Item P-306, Econocrete Subbase Course: Data were collected on five projects using compressive tests with only one project with thickness data. Econocrete Subbase Course appears to be more prevalent in the Southern Region, than in the Eastern Region.

- Item P-501, Portland Cement Concrete Pavement: Screening out small projects and compressive tests resulted in 18 acceptable flexural strength projects and were sufficient to develop operating curves. However, this data base contained only four projects with thickness data, which were insufficient to develop operating curves based on thickness.

2.3 Feasibility Study

The framework to conduct the feasibility study was divided into two steps:

- o Conduct a literature search for acceptable procedures that have been implemented in the field.

- o Based on the above, develop a plan to:

  - Outline the procedure for developing the Pay Adjustment Plan (PAP), considering applicability to this study.

  - Conduct the feasibility study.

The best means of developing PAP was to adopt the percent within limits (PAL) for specification acceptance plan, and the operating characteristic curve (OC) to relate the actual quantity measure to its probability of acceptance at any possible payment level.

The price adjustment is a policy-related measure determined by the user agency to be reasonable and equitable. The discrete price adjustment schedules for P-304 density and P-501 strength will be modified to a continuous adjustment curve. The price adjustment schedule of P-306 is currently based on thickness requirements; however, price adjustment on the basis of strength and thickness should be developed similar to that of Item P-501 in the current FAA specification.

Feasibility Study Approach

The objective of the feasibility study was to explore the desirability of, and the best means of, assessing adjustments on all selected materials, except for P-501. In this context, there were two steps to affect the feasibility study.

The first step was to consider the opinions of the various engineering staffs during the interviews and form a consensus of these opinions for each specification item. Recommendations were made to provide the best approach of a payment adjustment plan and an evaluation will be made of accuracy and precision of testing methods.

The second step was to evaluate the collected information and view its suitability for developing PAP. Following the first step and during the interviews, different opinions of the engineers and administrators about the use of Pay Adjustment Plans (PAP) for Items P-152, and P-209 were noticeable; PAP for Items P-304, P-306, and P-501 were generally accepted.

The following observations were representative of the opinions offered by the various consultants and airport agency staff engineers regarding PAP for Items P-152 and P-209:

- o Weaknesses and problems associated with these items are more expensive to correct, as it may require the removal of the surface and base course; whereas, problems with the surface layers are less expensive in comparison.

- o Experience shows that the contractor will factor into the bid price an allowance for penalties that might be imposed, which may result in a lesser quality product at a higher price.

- o Better pavement will result since the contractor will increase effort to achieve a higher quality control level in order to avoid penalties.

- o A weak spot in one area will not be offset by a 120 percent improvement in another. A weak spot will affect the performance of the entire runway.

- o There will be greater assurance of a high quality job since the contractor would likely recompact to receive 100 percent payment than to accept a penalty.

- o The use of PAP's should be included as an option for the contractor. In this case, a threshold level for recompaction should be specified as a requirement to comply with design and performance variables.

- o The use of PAP's will reduce the number of litigations, and will speed up the project by eliminating the questionable recompactions.

Information required to establish target specification limits and thresholds for recompaction for Items P-152 and P-209 are available. However, the impact of establishing these levels on performance and service life of the pavement as a whole will require further investigation.

As for the testing methodology for Items P-152 and P-209, again there was a diverse opinion about testing procedures; one was use of the sand cone method, ASTM D-1556, and the other was use of the nuclear gauge method, ASTM D-2922. FAA specification for Item P-209 allows both methods to be used, with the provision for adequate calibration of the nuclear gauge against standard material and against density obtained by the sand cone method at each project activity. The FAA specification does not allow for nuclear density testing on Item P-152.

As cited above, the second step in the feasibility study was directed to ascertain the above conclusions with objective evaluation derived from the collected data. Two methods to do this were:

- o To select subsets of data for each specification item and develop PAP trends (i.e., rough curves).
- o Select a statistically sound sample of data points for each specification item and evaluate its quality and reproducibility.

The second method was selected, wherein the analysis considered the following criteria:

- o Sample size (i.e. data quality): This measure was used to ensure that enough data was available to reach appropriate conclusions based on sound statistical methodology.
- o Data quality (i.e. variability): This measure was used to judge the variation of data <u>within</u> each project, as well as <u>between</u> projects, for each specification.
- o Analysis approach: Considering the collected data, a frame work for Work Element No. 2 analysis was outlined, accounting for the best means of assessing the pay adjustment plans.

Data Source and Availability

Data sets from 13 airports were considered for the analysis. The data included: 9 sets of P-152, 8 sets of P-209, 3 sets of P-304, and 5 sets of P-306. Due to the limitation of the computer package capability at this stage, the total number of data sets was limited to a maximum of ten. Additional data sets for Items P-304 and P-306 were not available at this time.

A list of the airports, with the corresponding specifications, are shown below:

Airport	Specification(s)*
1. Allentown-Bethlehem-Easton, PA	P-152, P-209
2. Chess-Lamberton, PA	P-152, P-209
3. Chesterland County, VA	P-152, P-304
4. DuBois-Jefferson County, PA	P-152
5. Greater Pittsburgh International, PA	P-152, P-209, P-306
6. Louisa County, VA	P-152
7. Pocono Mountains Municipal, PA	P-152, P-209
8. Manassas Mun./Davis Field, VA	P-152 (2 sets), P-304

9.	Lancaster, PA	P-209
10.	Mifflin County, PA	P-209 (2 sets)
11.	Blue Ridge, VA	P-304
12.	Harrisburg International,	P-306 (4 sets)
13.	Newark International, NJ	P-209

* One data set of each specification item, unless otherwise indicated.

Data Reduction and Manipulation

All raw data were transferred and organized on summary sheets. The summary sheets included the specification item, airport name, target specification, test number, and data test location (station and offset), density or strength values and percentage of target specification. These data were then entered in a data base (dBASE III Plus Software) for processing. At this initial stage, only the percentage of target specification was considered for the feasibility study analysis. The data sets that contained "retest" values of failed sections were eliminated.

The Biomedical Computer Programs (BMDP) package was used for statistical analysis. The data was transferred from dBASE III operating environment to other files (temporary) compatible with BMDP programs through an ASCII file. The BMDP procedures used are as follows:

- o BMD07D: Used to *find mean* ($\bar{X}$), standard deviation (σ), and coefficient of variation (CV).

- o BMD05D: Used to provide graphs and histograms.

- o BMD07D: Used to check data reliability.

Hardware/Software Requirements

The original approach of a payment adjustment schedule was generated for the FAA by Pennsylvania State University, field tested by Clemson University and applied to Item P-401. This study was to use the same methodology used by the original study, which had the statistical analysis performed on a mainframe computer with the final payment adjustment schedule in a chart form. This effort included writing programming on an IBM-compatible floppy data disks in amounts and contents as required to technically administer a computerized program, default files, and source program listing.

This required developing and performing the statistical analysis on an IBM compatible personal computer. The statistical analysis utilized the methodology similar to the original approach but in more detail.

- o Hardware requirements: IBM or compatible.

- o Software requirements: Several alternatives for use of available software packages have been identified. These are:

  - DBMS/analysis programs of Clemson (P-401) Study.

  - Engineering Economics Research, Inc.

  - Corps of Engineers programs.

  - Any other with the understanding that FAA's proprietary rights in the computer package is to be considered.

By reviewing the literature and contacting the relevant parties, the following was concluded:

- o The DBMS/analysis program of the Clemson (P-401) Study was developed for a mainframe environment and would need to be converted to a microcomputer environment for utilization in this study.

- o The PC-FOCUS was a self-contained DBMS/statistical analysis package; however, some of the required procedures for this study are not included (e.g. calculation of the area under the non-central t-distribution).

- o The Corps of Engineers used Lotus 1-2-3 for data manipulations and analyses on previous FAA projects. This program does not include the statistical procedures, as is required for this study.

- o Any other available source: Under this alternative, two options are available:

  - To use commercially available statistical packages (e.g. BMDP, SPSS, etc.) with DBMS (e.g. dBASE II, dBASE III, etc.) and develop interface softwares, as well as any required subroutine, not available in the commercial statistical package.

  - To convert the Clemson mainframe package to a microcomputer environment.

It should be noted that DBMS/statistical analysis procedure is an intermediate step required for the development of the pay adjustment plans, but not required by the end user. However, if FAA authority needs to fine-tune the adjustment plans when more data becomes available, or for any other reason, then the software of the intermediate step (or equivalent) will be needed.

Statistical Analysis and Results

Airports surveyed indicated that there are approximately 626 airports in the FAA Eastern Region, of which, data were collected on 30 airports, i.e. roughly 5 percent of all airports. 5 percent to 10 percent sample size is generally judged acceptable for the study purpose. Assuming that only 50 percent of the airports have construction projects relevant to this study, then the number of airports for each specification item, to satisfy sample size requirements, should be 15. Since airports can provide information on one or more construction projects, then the required number of airports (15 in this case) could be relaxed to about 10, provided that information on about 15 projects is available. The number of points required for each project depends on the required precision of the relevant specification items, as explained in the next paragraph.

The Weak Law of large numbers is often used by statisticians for determining the number of points required. This law is based upon "Tschebycheff's Inequality" which states that the probability that a random variable falls within $r.\sigma$ units of μ is greater than or equal to $1 - 1/r$. The mathematical expression for this law is:

$$\text{Prob.}(|\bar{x} - \mu| < \epsilon) > 1 - \delta \; ; \; \delta > \sigma^2/n\epsilon^2> \tag{2-1}$$

where,

$\bar{x}$ = the sample mean,
μ = the population mean,
$\epsilon = r * \sigma$ units by which the sample mean deviates from the population mean,
$1 - \delta$ = probability of occurrence,
σ = the population standard deviation,
n = sample size,
r = real number.

Of importance are the following assumptions:

$\epsilon = r * \sigma = 1 * \sigma$; i.e., it is desirable to have the mean of the scores of any item for a project deviation from the true value by not more than one standard deviating unit. Furthermore, if at least 95 percent confident that $\epsilon = 1 * \sigma$ is required, then $1 - \delta = .95$.

To sum, the following could be written:

$$1 - \delta = 1 - \sigma^2/n\epsilon^2 \qquad (2\text{-}2)$$

$$.95 = 1 - \sigma^2/n\sigma^2 = 1 - 1/n \text{ ; therefore } n = 20 \qquad (2\text{-}3)$$

The number of data points required for each project should not be less than 20, in order to be at least 95 percent confident that the mean value for any specification item of any project will not deviate by more than one standard deviation unit of the true value.

Sample Size Requirements

In line with the above discussion, the minimum number of projects required for each specification item was 15, and the minimum number of data points for each project was 20. The following was concluded:

- There was sufficient amount of data on specification Items P-152 and P-209 to carry out the feasibility study analysis and thereafter the development of PAP.
- There was not sufficient amount of data on specification Items P-306 and P-309 to carry out the feasibility study analysis and thereafter the development of PAP.
- Specification Item P-501 (thickness) was contractually excluded from the feasibility study.

As for Items P-304 and P-306, the question was not whether or not to collect more data for these two items, but whether or not it was desirable to do so. To answer this question, an analysis of the quality (or variablity) of the data was conducted. Two outcomes were possible:

- If the data quality was judged to be too variable, then it may not be desirable to collect more data.
- If the data quality was judged to be good, then it was desirable to collect more data.

Data Quality

The quality measures include the sample mean value, $\bar{x}$, the sample standard deviation, s, the coefficient of variation CV (CV = s/x), the maximun and minimum values, and the number of data points, N.

Most of the histograms show probability density function similar to the normal distribution; especially the graph for the "pool" of all projects of each specification item. Recalling the assumption that it is required to be 95 percent confident that the true value (μ of the spec. limit) does not deviate from the sample mean, $\bar{x}$, by more than one standard deviation, s, then:

$$\bar{x} * \mu/s = 1.645 \text{ and hence } |\bar{x} - \mu| = 1.645 \text{ s} \qquad (2\text{-}4)$$

By examining the values of Items P-152 and P-209, using the above formula, it could be concluded that all the average values are within the 95 percent confidence limits assumed.

The next question to be answered is whether or not the project's data for each specification item belong to the same population. To answer this question, a test of hypothesis was formulated as follows:

$$H_0 = \mu_1 = \mu_2 = \mu_3 = \ldots = \mu$$
(called the null hypothesis) (2-5)

H_1 = not all μ are equal
(called the alternative hypothesis) (2-6)

with decision rule being,

$F < F^*$ conclude H_0 (2-7)

$F > F^*$ conclude H_1 (2-8)

where,

μ_i = is the population mean of Project i for the relevant specification item,
H_0 = the hypothesis that the population means are equal,
H_1 = the hypothesis that not all the population means are equal,
F = test statistic for the above hypothesis,

F* = threshold value for F-statistic at any specified confidence limit.

By examining these results it can be concluded that the following projects contribute significantly to rejection of the null hypothesis:

Projects for Item P-152 = DUJ, W98, FKL,
Projects for Item P-209 = EWR209, RVL209A,
Projects for Item P-304 = ----,
Projects for Item P-306 = MDT688.

DUJ, W98, FKL, EWR209, RVL209, and MDT688 are data base file names based on the three letter airport designation.

When these projects were eliminated from the data base, improvement of the F-statistic was noticeable and the null hypothesis was accepted at the 99 percent confidence limit only for Items P-209 and P-304. However, Item P-152 is still rejected under the null hypothesis. It can be concluded that the project's data for this item may represent two different populations. Accordingly, the results of the t-statistic were used to group Item P-152 projects into two sets. When these two groups were examined, it was found that projects in one group represented cohesive soil data and projects in the second group represented cohesionless soil data. Each set was then treated as if it was representing a population.

The F-ratio was calculated and the null hypothesis was accepted only after eliminating Project DUJ from Set #1 and Project W98 from Set #2. The only item showing some variability is Item P-306. There are data available for only 5 projects. The reduction to 4 projects by eliminating Project MDT68C has improved the F-ratio and the elimination of Project MDT68B further improved the F-ratio from 21.2 to 12.5. However, the null hypothesis was still rejected. It is believed that if more data was available, the procedure similar to the one used for Item P-152 may prove successful.

Conclusions:

In conclusion, the feasibility study indicated the following:

- Statistical analysis could be performed on an IBM-compatible personal computer.

- Analysis of the data obtained indicates that there was sufficient quality data to develop PAP for Items P-152 and P-209, and it was feasible to develop PAP for these two items.

- There was not sufficient data at this point to develop PAP for Item P-304. However, it was desirable to collect data for this item since the analysis of collected data indicates that it was of good quality.

- There was not sufficient data at this point to develop PAP for Item P-306. However, the data variability was judged to be marginal. One reason for this variation was the offset in the age at which the samples were tested (e.g. 36 days instead of 28 days). However, it was concluded that it was desirable to collect more data for this item, and select test data for only 28-day results.

- Analysis of data for Items P-152 included two projects with the density values measured by the nuclear gauge. It was noted, however, that the effect of these two projects on the results is minor.

- For Item P-152, it appeard that the variability of the material depends on the subgrade type (i.e., cohesive or cohesionless soil) more strongly than the type of test performed (i.e., sand cones versus nuclear gauge). In effect, a PAL specification could be developed for each of the two soil types with the test specification of the sand cone method. However, data for the nuclear gauge will be retained in the data base for future use.

- The best means of developing a PAP was to develop a PAL specification for each item and use an OC curve to relate the actual quantity measured to its probability of acceptance at any possible payment level. In addition, a price adjustment schedule should be developed and used as a general policy measure for all items. Price adjustment should be fair and equitable to all contractors, as well as reasonable to the airport authority.

- The opinions of the consulting engineers and airport agency staff engineers were too diverse to develop a position on the desirability of developing PAP adjustment plans for the specifications other than P-501. However, the plans should be developed and implemented on a selective basis until its practicality or otherwise can be determined.

- The testing procedures and equipment in use are sufficiently accurate to assure reasonable values for purposes of pay adjustment plans.

TABLE 2.1
DATA COLLECTION VISITS

A meeting was held with the FAA Eastern Region Airports Division, Safety and Standards Branch as follows:

02/11/87	Eastern Region	Mr. Carl Steinhauer, Manager Mr. William DeGraaf

Meetings were held with the four FAA District Offices as follows:

*03/16/87	Washington ADO	Mr. William Whittle, Chief Mr. Terry Page Ms. Lori Lehnard
04/03/87	New York ADO	Mr. Robert Mendez, Manager Mr. Tom Felix Mr. Robert A. Bacza Mr. Kenneth P. Knoll Mr. Timothy Dyer Mr. John Moretto
04/08/87	Harrisburg ADO	Mr. Dan Cassidy Mr. Fred Waldmer
*04/10/87	Beckley AFO	Mr. Joseph H. Scheff, Manager Mr. Jim Tartal

The above listed meetings with the FAA District Offices resulted in the following meetings with airports, airport consultants/ engineers and airport authorities:

*03/17/87	Hayes, Seay, Mattern, Mattern; Rockville, MD
*03/24/87	CH2M Hill; Reston, VA
03/25/87	Greiner Engineering; Timonium, MD
03/25/87	Washington National Airport, Engineering Div., Washington, D.C.
*03/26/87	Manassas Municipal Airport; Manassas, VA
03/26/87	R.E. Byrd International Airport; Richmond, VA
*03/27/87	Norfolk International Airport; Norfolk,VA
*03/27/87	R. Kenneth Weeks, Engineer; Norfolk, VA
*05/11/87	Washington County Airport; Washington, PA
*05/11/87	Michael Baker, Jr., Inc.; Beaver, PA
*05/12/87	Biro-Tech, Inc.; Coraoplis, PA
*05/13/87	Pittsburgh International Airport, Pittsburgh, PA
*05/27/87	Harrisburg international Airport, Middletown, PA
*05/27/87	Lancaster Airport, Lancaster, PA
*05/28/87	Sanders, Wall & Wyre, State College, PA
*05/28/87	Mifflin County Airport, Reedsville, PA
*06/01/87	Philadelphia International Airport, Philadelphia, PA

TABLE 2.1 (continued)

*06/02/87	Pottstown-Limerick Airport, Pottstown, PA
*06/02/87	Atlantic Engineers & Contractors, Inc., Kimberton, PA
*06/02/87	G. Edwin Pidock Co., Allentown, PA
*06/10/87	FAA Technical Center-Atlantic City Airport, Atlantic City, NJ
06/16/87	Washington National Airport, Washington, D.C.
06/16/87	Greiner Engineering, Washington National Airport
06/18/87	EI Group, East Orange, NJ
*06/23/87	Hoyle, Tanner & Associates, Inc., Bedford, NH
*06/24/87	Calcerinos-Spina, Liverpool, NY
*06/25/87	Nigara Frontier Transportation Authority, Buffalo, NY
*	Delta Associates, P.E., Inc. Richmond, VA
*	Talbert, Cox and Associates, Wilmington, NC
*	The LPA Group of North Carolina, p.a., Raleigh, NC
*	Roy D. McQueen, Oakton, VA
*	L. Robert Kimball & Associates
*	New York Port Authority, New York, NY
*	Pan American World Airways, Inc., Teterboro, NJ
*	Lee-Simpson Associates, Inc., Dubois, PA
*	Stilson & Associates, Inc., Columbus, OH

* Indicates data received.

TABLE 2.2
AIRPORT TEST DATA COLLECTED BY SPECIFICATION

Pavement construction test data collected from the FAA Eastern Region is as follows:

P-152	Excavation & Embankment	57 Projects
P-209	Crushed Aggregate Base Course	40 Projects
P-304	Cement Treated Base Course	12 Projects
P-306	Econocrete Subbase Course	
	Compressive Strength Data	05 Projects
	Thickness Data	01 Project
P-501	Portland Cement Concrete Pavement	
	Flexural Strength Data	27 Projects
	Thickness Data	04 Projects

This test data have been collected from the following airports (not all the data were found to be usable):

- Item P-152, Excavation and Embankment:

  1. Chesterfield County Airport, Chesterfield, VA (2 Projects)
  2. Louisa County Airport, Louisa, VA
  3. Buckhannon-Upshur County Airport, Buckhannon, WV
  4. Allentown-Bethlehem-Easton, Allentown, PA (4 Projects)
  5. Chester County-G.O. Carlson, Coatesville, PA
  6. Chess-Lamberton Airport, Franklin, PA
  7. DuBois-Jefferson County, DuBois, PA
  8. Lancaster Airport, Lancaster, PA (2 Projects)
  9. Westmoreland County Airport, Latrobe, PA
  10. Pocono Mountains Municipal, Mount Pocono, PA (2 Projects)
  11. Greater Pittsburgh International, Pittsburgh, PA (2 Projects
  12. Pottstown Limerick Airport, Pottstown, PA
  13. Washington County Airport, Washington, PA (4 Projects)
  14. Rochester Monroe County Airport, Rochester, NY
  15. Syracuse-Hancock International, Syracuse, NY (3 Projects)
  16. Virginia Highlands Airport, Abingdon, VA (2 Projects)
  17. Roanoke Municipal/Woodrum Airport, Roanoke, VA (4 Projects)
  18. Easton Municipal Airport, Easton, MD
  19. Frederick Municipal Airport, Frederick, MD
  20. New Kent County Airport, Quinton, VA (2 Projects)
  21. Clarion County Airport, Clarion, PA (2 Projects)
  22. Culpeper Municipal/T.I. Martin Airport, Culpeper, VA
  23. Washington County Regional Airport, Hagerstown, MD (2 Projects)

TABLE 2.2 (continued)

24. Greater Buffalo International Airport, Buffalo, NY
25. Charlottesville-Albermarie Airport, Charlottesville, VA
26. Essex County Airport, Caldwell, NJ (2 Projects)
27. East Hampton Airport, East Hampton, NY
28. Niagara Falls International Airport, Niagara Falls, NY (2 Projects)
29. Mifflin County Airport, Reedsville, PA (2 Projects)
30. Mercer County Airport, Bluefield, WV
31. Martin State Airport, Baltimore, MD
32. Manassas Municipal/Davis Field Airport, Manassas, VA (2 Projects)
33. Teterboro Airport, Teterboro, NJ (2 Projects)

o Item P-209, Crushed Aggregate Base Course:

1. Allentown-Bethlehem-Easton, Allentown, PA (7 Projects)
2. Chess-Lamberton Airport, Franklin, PA
3. Lancaster Airport, Lancaster, PA
4. Westmoreland County Airport, Latrobe, PA (2 Projects)
5. Pocono Mountains Municipal, Mount Pocono, PA
6. Greater Pittsburgh International, Pittsburgh, PA (2 Projects)
7. Clinton County Airport, Plattsburgh, NY
8. Syracuse-Hancock International, Syracuse, NY (3 Projects)
9. Newark International Airport, Newark, NJ
10. Virginia Highlands Airport, Abingdon, VA
11. Chesterfield County Airport, Chesterfield, VA
12. Roanoke Municipal/Woodrum Airport, Roanoke, VA
13. Danville Municipal Airport, Danville, VA
14. Easton Municipal Airport, Easton, MD
15. New Kent County Airport, Quinton, VA (2 Projects)
16. Patrick Henry International Airport, Newport News, VA (2 Projects)
17. Indiana County/Jimmy Stewart Airport, Indiana, PA
18. VPI/Virginia Tech Airport, Blacksburg, VA (2 Projects)
19. Doylestown Airport, Doylestown, PA
20. Reading Municipal Airport, Reading, PA
21. Baltimore-Washington International, Baltimore, MD
22. Essex County Airport, Caldwell, NJ (2 Projects)
23. East Hampton Airport, East Hampton, NY
24. La Guardia Airport, New York, NY
25. Washington National Airport, Washington DC
26. Martin State Airport, Baltimore, MD

TABLE 2.2 (continued)

- Item P-304, Cement Treated Base Course:

  1. Martin State Airport, Baltimore, MD
  2. Chesterfield County Airport, Chesterfield, VA
  3. Blue Ridge Airport, Martinsville, VA (2 Projects)
  4. Virginia Highlands Airport, Abingdon, VA
  5. Roanoke Municipal/Woodrum Airport, Roanoke, VA (2 Projects)
  6. Culpeper Municipal/T.I. Martin Airport, Culpeper, VA
  7. Washington County Regional Airport, Hagerstown, MD
  8. Manassas Municipal/Davis Field Airport, Manassas, VA
  9. Salisbury-Wicomico County Airport, Salisbury, MD
  10. Washington National Airport, Washington D.C.

- Item P-306, Econocrete Subbase Course:

  1. Harrisburg International, Middletown, PA (4 Projects)
  2. Greater Pittsburgh International, Pittsburgh, PA

- Item P-501, Portland Cement Concrete Pavement:

  1. Dulles International, Washington, D.C.
  2. Baltimore-Washington International, Baltimore, MD
  3. Charlottesville-Albermarle, Charlottesville, VA
  4. Norfolk International, Norfolk, VA (3 Projects)
  5. Salisbury-Wicomico County, Salisbury, MD
  6. Greater Pittsburgh International, Pittsburgh, PA (2 flex & 2 tk Projects)
  7. Greater Buffalo International, Buffalo, NY (3 flex & 1 tk Projects)
  8. Rochester Monroe County, Rochester, NY
  9. Syracuse-Hancock International, Syracuse, NY (2 Projects)
  10. FAA Tech Center, Atlantic City, NJ (1 flex & 1 tk Projects)
  11. Patrick Henry International Airport, Newport News, VA (2 Projects)
  12. Beaver County Airport, Beaver, PA
  13. Philadelphia International Airport, Philadelphia, PA
  14. Harrisburg International Airport, Middletown, PA (3 Projects)
  15. Niagara Falls International Airport, Niagara Falls, NY (2 Projects)
  16. Martin State Airport, Baltimore, MD
  17. Manassas Municipal/Davis Field Airport, Manassas, VA

TABLE 2.3
AIRPORT TEST DATA USED AS DATA BASE

The test data received were screened and analyzed by a pavement engineer for completeness, quantity, and quality and compared to the airport selection criteria. All projects that were found acceptable were then entered into a computer data base to be used for statistical analysis.

These acceptable projects were as follows:

P-152	Excavation & Embankment (Sand cone data)...	26 Projects
P-209	Crushed Aggregate Base Course	
	(Sand cone data)............................	21 Projects
P-304	Cement Treated Base Course..................	05 Projects
P-306	Econocrete Subbase Course	
	Compressive Strength Data...................	05 Projects
	Thickness Data..............................	01 Project
P-501	Portland Cement Concrete Pavement	
	Flexural Strength Data......................	18 Projects
	Thickness Data..............................	03 Projects

The valid, usable data were from the following airports:

o Item P-152, Excavation and Embankment:

1. Chesterfield County Airport, Chesterfield, VA (2 Projects)
2. Allentown-Bethlehem-Easton, Allentown, PA (4 Projects)
3. Chester County-G.O. Carlson, Coatesville, PA
4. Chess-Lamberton Airport, Franklin, PA
5. Westmoreland County Airport, Latrobe, PA
6. Pocono Mountains Municipal, Mount Pocono, PA (2 Projects)
7. Pottstown Limerick Airport, Pottstown, PA
8. Washington County Airport, Washington, PA (4 Projects)
9. Syracuse-Hancock International, Syracuse, NY (3 Projects)
10. Virginia Highlands Airport, Abingdon, VA (2 Projects)
11. Roanoke Municipal/Woodrum Airport, Roanoke VA (4 Projects)
12. Easton Municipal Airport, Easton, MD
13. New Kent County Airport, Quinton, VA (2 Projects)
14. Washington County Regional Airport, Hagerstown, MD

o Item P-209, Crushed Aggregate Base Course:

1. Allentown-Bethlehem-Easton, Allentown, PA (6 Projects)
2. Pocono Mountains Municipal, Mount Pocono, PA
3. Clinton County Airport, Plattsburgh, NY

TABLE 2.3 (Continued)

4. Syracuse-Hancock International, Syracuse, NY (3 Projects)
5. Newark International Airport, Newark, NJ
6. Virginia Highlands Airport, Abingdon, VA
7. Chesterfield County Airport, Chesterfield, VA
8. Roanoke Municipal/Woodrum Airport, Roanoke, VA
9. Easton Municipal Airport, Easton, MD
10. New Kent County Airport, Quinton, VA (2 Projects)
11. Doylestown Airport, Doylestown, PA
12. Reading Municipal Airport, Reading, PA
13. La Guardia Airport, New York, NY

- Item P-304, Cement Treated Base Course:

1. Chesterfield County Airport, Chesterfield, VA
2. Blue Ridge Airport, Martinsville, VA
3. Virginia Highlands Airport, Roanoke, VA
4. Roanoke Municipal/Woodrum Airport, Roanoke, VA (2 Projects)

- Item P-306, Econocrete Subbase Course:

1. Harrisburg International, Middletown, PA (4 Projects)
2. Greater Pittsburgh International, Pittsburgh, PA

- Item P-501, Portland Cement Concrete Pavement:

1. Dulles International, Washington, D.C.
2. Baltimore-Washington International, Baltimore, MD
3. Charlottesville-Albermarle, Charlottesville, VA
4. Norfolk International, Norfolk, VA
5. Salisbury-Wicomico County, Salisbury, MD
6. Greater Pittsburgh International, Pittsburgh, PA (2 flex & 2 tk Projects)
7. Greater Buffalo International, Buffalo, NY (3 flex & 1 tk Projects)
8. Rochester Monroe County, Rochester, NY
9. Syracuse-Hancock International, Syracuse, NY (2 Projects)
10. FAA Tech Center, Atlantic City, NJ (1 flex & 1 tk Projects)
11. Patrick Henry International Airport, Newport News, VA
12. Philadelphia International Airport, Philadelphia, PA
13. Niagara Falls International Airport, Niagara Falls, NY (2 Projects)

TABLE 2.4
DATA COLLECTION SOURCES

Pavement test data sources, for Task C, were as follows:

1. Atlantic Engineers & Consultants, Inc., Kimberton, PA, Morris W. Holman, Jr.; Chester County Airport, Coatesville, PA; Pottstown Limerick Airport, Pottstown, PA.

2. Biro Tech, Inc., Corapolis, PA, Richard W. Dorothy; Beaver County Airport, Beaver, PA; Clarion County Airport, Clarion, PA; Indiana County/Jimmy Stewart Airport, Indiana ,PA.

3. Calocerinos and Spina, Liverpool, NY, Bob Masterpol; Rochester Monroe County Airport, Rochester, NY; Syracuse-Hancock International Airport, Syracuse, NY.

4. CH2M Hill, Reston, VA, Micheal L. Churchill; Louisa County Airport, Louisa, VA.

5. Commonwealth of Pennsylvania, Bureau of Aviation, Middletown, PA, Francis F. Strouse; Harrisburg International Airport, Middletown, PA.

6. Delta Associates P.E., Inc., Richmond, VA, Charles Lamb; Easton Municipal Airort, Easton, MD; Fredrick Municipal, Frederick, MD; Washington County Regional Airport, Hagerstown, MD; Virginia Highlands Airport, Abingdon, VA; Chesterfields County Airport, Chesterfield, VA; Culpeper Municipal/Martin Airport, Culpeper, VA; Danville Municipal Airport, Danville, VA; Roanoke Municipal/Woodrum Airport, Roanoke, VA; New Kent County Airport, Quinton, VA.

7. FAA, Technical Center, Atlantic City, NJ, Bob J. Warner; Atlantic City Airport, Atlantic City, NJ.

8. FAA, Washington District Office, Falls Church, VA, William Whittle; Chesterfield County Airport, Chesterfield, VA.

9. FAA, West Virginia Field Office, Beaver, WV, Joseph H. Scheff; Mercer County Airport, Princeton, WV.

10. G. Edwin Pidcock Co., Allentown, PA, Sherwood F. Clause; Allentown-Bethlehem-Easton Airport, Allentown, PA; Pocono Mountain Municipal Airport, Mount Pocono, PA.; Reading Municipal Airport, Reading PA; Doylestown Airport, Doylestown, PA.

TABLE 2.4 (Continued)

11. Greater Pittsburgh International Airport, Pittsburgh, PA, William C. Stuenkel; Greater Pittsburgh International Airport, Pittsburgh, PA.

12. Hayes, Seay, Mattern and Mattern, Rockville, MD, Charles H. Porter; Baltimore/Washington International Airport, Baltimore, MD; Blue Ridge Airport, Martinsville, VA; Martin State Airport, Baltimore, MD; Norfolk International Airport, Norfolk, VA; Suffolk Municipal Airport, Suffolk, VA.

13. Hoyle, Tanner & Asociates, Inc., Bedford, NH, Barry W. Lussier; East Hampton Airport, East Hampton, NY; Essex County Airport, Fairfield, NJ.

14. Lancaster Airport, Lancaster, PA, Norman Lamar; Lancaster Airport, Lancaster, PA.

15. Lee-Simpson Associates, Inc., DuBois, PA, Edward S. Nasuti; DuBois-Jefferson County Airport, DuBois, PA; Chess-Lamberton Airport, Franklin, PA; Westmoreland County Airport, Latrobe, PA.

16. The LPA GROUP of North Carolina, P.A., Raleigh, NC., James C. Farthing; Virginia Tech Airport, Blacksburg, VA.

17. L. Robert Kimball & Associates, Ebensburg, PA, William R. Reeves and Rick Genday; Buckhannon-Upshur County Airport, Buckhannon, WV.

18. Michael Baker, Jr., Inc., Beaver, PA, Allan R. Berenbrok; Washington County Airport, Washington, PA.

19. New York Port Authority, Jamaica, NY, Ray Finnegan; Newark International Airport, Newark, NJ; La Guardia Airport, New York, NY.

20. Niagara Frontier Transportation Authority, Buffalo, NY, Walt Zmuda; Greater Buffalo International Airport, Buffalo, NY; Niagara Falls Airport, Niagara Falls, NY.

21. Pan American World Airways, Inc., Teterboro Airport, NJ, Charles W. Kurtz; Teterboro Airport, Teterboro, NJ.

22. Philadelphia International Airport, Philadelphia, PA, Jay Beratan; Philadelphia International Airport, Philadelphia, PA.

23. R. Kenneth Weeks, Engineers, Norfolk, VA, Wilbur D. Marshall; Norfolk International Airport, Norfolk, VA.

TABLE 2.4 (Continued)

24. Roy D. McQueen & Associates, Oakton, VA, Roy D. McQueen; Charlottesville-Ablemarle Airport, Charlottesville, VA; Dulles International Airport, Washington, D.C.; Manassas Municipal Airport, Manassas, VA, Wicomico County Airport, Salisbury, MD.

25. Sanders, Wall and Wyre, State College, PA, Charles Wall; Mifflin County Airport, Reedsville, PA.

26. Stilson and Associates, Inc., Columbus, OH, David L. Weir; Wheeling-Ohio County Airport, Wheeling, WV.

27. Talbert, Cox and Associates, Inc., Wilmington, NC, John Talbert, III; Patrick Henry Airport, Newport News, VA.

Pavement test data sources, for Task F, were as follows:

28. FAA, Washington District Office, FAlls Church VA, William Whittle and Kenneth C. Jacobs; Dulles International Airport, Washington D.C.

29. Greiner Engineering Services, Inc., Baltimore, MD; Baltimore/Washington International Airport, Baltimore, MD.

30 Mellon Stuart Company, Dick Enterprisers, Pittsburgh, PA, James A. Long and Kevin Wiley; Greater Pittsburgh International Airport, Pittsburgh, PA.

31 National Ready Mixed Concrete Association and the National Aggregates Association, Silver Spring, MD, Richard C. Meininger; Wichita Mid-Continent Airport, Wichita, KA.

32 R. Kenneth Weeks, Engineers, Norfolk, VA, Edward L. Owens; Norfolk International Airport, Norfolk, VA.

3. QUALITY CONTROL CONSIDERATIONS

3.1 Basic Concepts from Quality Control

This study was primarily concerned with use of statistically based ideas in the application of product quality control, as such a few comments initially on quality control are warranted.

Quality control is a general term that includes two different types of controls over the product. These are: accept/reject control and process control. Acceptance/rejection control is concerned with monitoring product quality as the product is delivered in batches or lots to the buyer. Accept/reject control involves the decision to accept or reject a lot based on a random sample from the lot. Process control, however, is concerned with the detection of changes in product performance and taking the necessary action to control the process to correct the change in performance. Accept/reject control is primarily the concern of the buyer while process control is primarily the concern of the producer. Both components of quality control, accept/reject and process controls, are based on statistical theories and associated sampling methods. A number of sampling schemes exist and are used in the various specifications. A brief discussion of sampling needs for accept/reject control will be presented in what follows. Since process control is not the explicit concern of this study, no further discussion of this component will be given.

3.2 The Accept/Reject Control Component

A preliminary judgement and an essential part of accept/reject control is an estimation of the material quality. In fact, when a producer delivers a lot of material, the engineer (consumer) needs to know the quality of the material in the lot. In the current FAA approach, if the lot quality is found to be at or above the consumer's upper quality standard, the consumer accepts the lot and pays the producer in full. On the other hand, if the lot quality is found to be at or below the consumer's lower quality standard, the consumer rejects the lot and pays the producer nothing. If the lot quality is found to be between the two quality standards, the consumer accepts the lot and pays the producer a reduced price according to a payment adjustment schedule, where the reduction depends on the level of lot quality.

The above scenario depends on the assumption that the quality of a lot can be known with certainty. Unfortunately, complete knowledge of lot quality requires 100% inspection - a task that is usually prohibitively expensive and sometimes impossible (destructive testing). An alternative to obtaining complete knowledge of quality relies on sampling and statistical acceptance plans to provide an estimate of lot quality.

An estimate of lot quality is subject to sampling variability. This implies that the payment decision for a few lots of suitable quality material would be penalized with rejection or a payment adjustment, and a few lots of poor quality material would get full payment. These two situations should be controlled in the payment adjustment.

3.3 Previous Work of Interest

Statistical acceptance plans have been in use for some time. A thorough treatment of the subject appeared as early as 1957, in the military publication MIL-STD 414.[1] A key element of that work is the formula for the best - uniformly minimum variance unbiased (UMVU) - estimate of the percentage of a lot of material above an arbitrary limit (PAL). A recent treatment of statistical acceptance plans appears in texts by Duncan [2] and Wetherill [3].

The methodology in MIL-STD 414 was applied to pavements in the middle 1970's by Willenbrock and Kopac [5,13]. This same methodology was applied to bituminous airport runway materials in 1979 by Burati and Willenbrock, [6]. Payment adjustment schedules were used in these applications [6,7]. The following work draws heavily on previous results for the statistical acceptance plan.

3.4 Accept/Reject Parameters

As mentioned earlier, primary tasks in this work are to develop a statistical acceptance plan and an integrated payment schedule that successfully deals with the variability in the estimate of lot quality. Using well known statistical procedures it was possible to determine the probability of acceptance for a specific lot quality. Typically, two numbers are determined that quantify the lower bound of acceptable quality and the upper bound of unacceptable quality. If 100% error-free inspection could be performed, these two numbers would be the same. In this scenario, the lot would be accepted if it met or exceeded the given quality limit; otherwise, the lot is rejected. Such an acceptance plan is illustrated by the operating characteristic (OC) curve of Figure 3.1.

Even if the inspection were nondestructive, 100% inspection, unless necessary, should be avoided if for no other reason than for cost considerations. Quality Control (QC) practices suggest choosing a sample of n items that will be the basis of any acceptance/rejection of the lot of material. Since the sample provides only an estimate of the lot quality, the choice of the two numbers mentioned above is based on probalistic concerns.

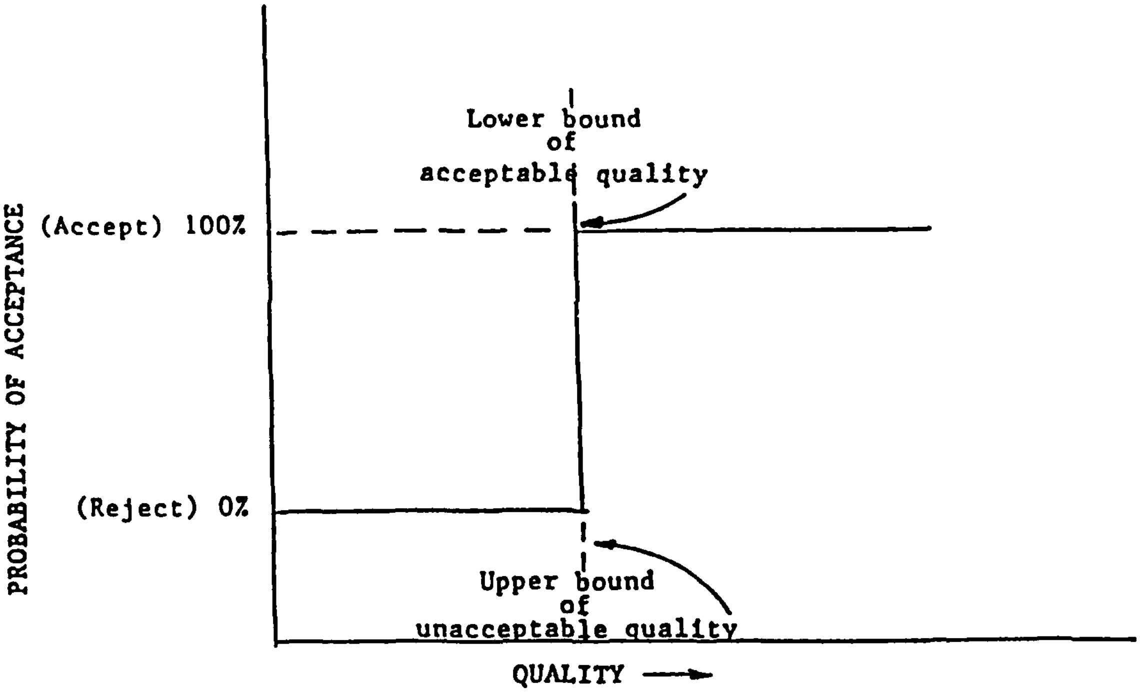


FIGURE 3.1. TYPICAL OPERATING CHARACTERISTIC CURVE

The first number is often called the Acceptable Quality Limit, (AQL). The AQL is the minimum acceptable quality and is assigned a 100 $(1 - \alpha)$% probability of being accepted. The probability of rejecting a lot with a quality level equal to the AQL is called the producer's risk, α, which is set to a relatively low value (often .05). The second number is termed the Unacceptable Quality Limit, (UQL), [other terms for this are the Rejection Quality Limit (RQL) or Lot Tolerance Percent Defective (LTPD)]. It has a probability of acceptance equal to β, called the consumer's risk. This represents a quality level that the organization (often referred to as the consumer) wants a low probability of accepting. A value of .10 is typical for β.

In standard Quality Control (QC) practice, each lot is accepted or rejected. This results in either 100% or 0% payment for the lot. The expected payment for lots produced at a consistent quality level is 100 times (Probability of Acceptance) given the quality level. If the lots were consistently produced at the AQL, the expected payment would be 100 $(1 - \alpha)$%. Similarly for lots produced at the UQL, the expected payment is 100 (β)%.

In most QC cases historical data provides both mean and variability estimates of the material to be produced, so that the AQL and UQL may be selected to meet the desired quality goals. For this study, the FAA desires an investigation into statistically based pay factors. This investigation selects a possible AQL and UQL pair to demonstrate the use of the proposed statistical procedure. In practice, the FAA must work closely with the producers to determine realistic values for these quality parameters.

The current FAA practice uses a pay adjustment factor to determine the actual payment to a contractor on a lot by lot basis. The statistical procedure proposed in this report is based on an estimate of quality, as described later in this report. This procedure also computes a pay adjustment factor on a lot by lot basis. In classical QC inspections, a lot would receive either 100% or 0% pay, as mentioned above. A lot by lot statistical procedure should result in roughly the same expected pay for a given lot quality, as the classical QC approach. Thus, a lot with a true quality level equal to the AQL should have an expected pay factor equal to $100(1 - \alpha)\%$, while a lot with a quality level equal to the UQL, should have an expected pay factor of $100 (\beta)\%$.

In the following sections, a statistical acceptance plan and a payment adjustment schedule for each of five materials used in airport runway construction will be developed. Although the accomplished goals shown in this report are for only one of the five materials (P-501 Concrete, flexural strength), developments of an acceptance plan and a payment adjustment schedule, where appropriate, for other airport pavement materials are similar.

The integrated system of a statistical acceptance plan and a payment adjustment schedule must be practical and serve the purpose intended by the user: to encourage suitable quality production by rewarding producers of suitable quality material with full pay, and penalizing producers of unsuitable quality material with a payment adjustment or rejection.

4. TECHNICAL DISCUSSION

4.1 Approach

This chapter presents the details of the development of a statistical acceptance plan and an integrated payment adjustment schedule for P-501 Concrete. The development of an integrated payment adjustment schedule depends on the specific statistical acceptance plan chosen by the consumer, so the development of the acceptance plan is presented first in Section 4.2 and is followed by the development of the corresponding payment adjustment schedule in Section 4.3.

Section 4.2 begins with an outline of the basic steps of the general statistical acceptance plan and is followed by a discussion of the set of values that must be chosen by the consumer in order to specify a particular acceptance plan: AQL, UGL, α, and β. Next, definitions of unit and lot quality for P-501 Concrete are given. This is followed by a discussion of the method of obtaining the best estimate of lot quality. Formulas for calculating the estimates are given for various lot sample sizes.

Next is a discussion of an analysis of data and the rationale for choosing the values of AQL and UQL, followed by a discussion of the choices for α and β. This is followed by a presentation of the procedure for taking these values and calculating the lot sample size and acceptance value. This is the final step in specifying a particular statistical acceptance plan and the formulas are applied to the values for P-501 Concrete and the results are presented.

Before continuing to the payment adjustment schedule, the operating characteristic (OC) is introduced. The OC is derived from the specific statistical acceptance plan and is used in the development of the payment adjustment schedule.

Section 4.3 begins with a review of the statistical acceptance plan for P-501 Concrete, developed in the preceding section, and is followed by a discussion of the basic philosophy of an integrated payment adjustment schedule. Next, a discussion of the statistical acceptance plan and integrated payment adjustment schedule, used with the P-401 Asphalt, is presented. Then, the payment adjustment schedule for P-501 Concrete is presented and discussed. Finally, comments regarding application of the technology to the other materials of interest from this work are presented.

4.2 Statistical Acceptance Plan

Acceptance sampling is a statistical procedure used to achieve quality assurance [2,3]. For a given lot of material, the procedure consists of the following: (1) Draw a fixed number of samples from the lot, (2) Measure the quality of each sample, (3) Compute an estimate of lot quality from the sample measurements, and (4) Accept or reject the lot, depending on whether the estimate is above or below an acceptable value. The complete procedure consists of repeating the steps for each lot in a series of lots.

To specify a particular acceptance plan, four values are chosen: the acceptable quality limit (AQL), the unacceptable quality limit (UQL), the producer's risk (α), and the consumer's risk (β). These values are used to compute the acceptable value and the lot sample size. The calculations ensure that for lots produced at the AQL, there will be a small probability of rejection (α), and for lots produced at the UQL, there will be a small probability of acceptance (β). In this way, quality assurance is achieved. The consumer knows that in the long run, 100 $(1-\alpha)$% of the lots of acceptable quality will be accepted and 100 $(1-\beta)$% of the lots of unacceptable quality will be rejected.

The measure of quality for a unit of P-501 Concrete is the 28-day flexural strength, measured in pounds per square inch (psi) [4]. The corresponding definition of quality for a lot of P-501 Concrete is the percentage of units in the lot that have a 28-day flexural strength greater than a fixed (but arbitrary) limit. Applying the normal distribution model, we assume that the unit flexural strength values in a lot are normally distributed with a particular mean and standard deviation. Under this model, the <u>p</u>ercentage <u>a</u>bove a given <u>l</u>imit (PAL) is equal to 100 Φ $[(\mu-L)/\sigma]$ where Φ is the standard normal distribution function, μ is the lot mean, L is the limit, and σ is the lot standard deviation [See Appendix A].

For a given lot and limit, the PAL can be found by (1) finding the number of units with test values greater than the limit and dividing by the total number of units, and (2) finding the mean and standard deviation of all the unit test values and computing 100Φ $[(\mu-L)/\sigma]$; both are impractical because they require all the units to be tested. An alternative is to estimate PAL and use the estimate as a proxy for the unknown PAL. The best (unbiased minimum variance) estimator of PAL is a function of the sample quality index and depends on the lot sample size [5]; the sample quality index is computed from the sample average and the sample standard deviation. The sample average, sample standard deviation, sample quality index, and best estimator formulas are, respectively, Average: $$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i, \qquad (4\text{-}1)$$

Standard Deviation: $$S = \left[\frac{1}{(n-1)}\sum_{i=1}^{n} (X_i - \bar{X})^2\right]^{1/2}, \qquad (4\text{-}2)$$

Quality Index: $$Q = \frac{(\bar{X}-L)}{S}, \qquad (4\text{-}3)$$

Estimated PAL: $$EPAL_n = 100\left(1 - \int_0^A \text{beta } (X; n/2 - 1)\, dX\right), \qquad (4\text{-}4)$$

$$= 100\, \Phi(Q)$$

where,

n = lot sample size,

X_i = ith sample value,

$EPAL_n$ = estimator of PAL for lot sample size equal to n,

A = max [0, 1/2 - 1/2 Q $(n^{1/2}/n-1)$],

beta = (X; n/2 - 1) = beta density with $\alpha = \beta = n/2 - 1$.

Values of $EPAL_n$ have been tabulated for various Q and for n from three to 12, eliminating the burden of working with Equation (4-4) [5]. However, using a table of integrals and the binomial formula, Equation (4-4) has been reduced to a set of algebraic equations (procedure outlined in Appendix B) eliminating the need for the tables:

$$EPAL_3 = 100\,\{.5 + (1/\pi \text{SIN}^{-1}(1-2A)\}, \qquad (4\text{-}5)$$

$$EPAL_4 = 100\,\{1 - A\}, \qquad (4\text{-}6)$$

$$EPAL_5 = 100\,\{(2/\pi)\ (1-2A)\ (A-A^2)^{1/2}\} + EPAL_3, \qquad (4\text{-}7)$$

$$EPAL_6 = 100\,\{1 - 3A^2 + 2A^3\}, \qquad (4\text{-}8)$$

$$EPAL_7 = 100\,\{(16/3\pi)\ (1-2A)\ (A-A^2)^{3/2}\} + EPAL_5, \qquad (4\text{-}9)$$

$$EPAL_8 = 100\,\{1 - 10A^3 + 15A^4 - 6A^5\}, \qquad (4\text{-}10)$$

$$EPAL_9 = 100\ \{(256/15\pi)\ (1-2A)\ (A-A^2)^{5/2})\} + EPAL_7, \quad (4\text{-}11)$$

$$EPAL_{10} = 100\ \{1 - 35A^4 + 84A^5 - 70A^6 + 20A^7\}, \quad (4\text{-}12)$$

$$EPAL_{11} = 100\ \{(2048/35\pi)\ (1-2A)\ (A-A^2)^{7/2})\} + EPAL_9, \quad (4\text{-}13)$$

$$EPAL_{12} = 100\ \{1 - 126A^5+420A^6-540A^7 + 315A^8 + 70A^9\}, \quad (4\text{-}14)$$

An important fact about estimating PAL is that as n increases, 100Φ (Q) approaches $100\Phi\ [(\mu-L)/\sigma]$. This implies that for n large enough (perhaps greater than about 25), an approximate value for PAL can be calculated by finding Φ (Q) in a standard normal table. This is much simpler than using Equation (4-4).

The AQL and UQL that are used in the discussion that follows were computed from an analysis of the available historical data for P-501 Concrete. Simply put, the AQL is the minimum level of quality that the consumer desires to accept with high probability, $(1-\alpha)$, and the UQL is the maximum level of quality that the consumer desires to reject with a high probability $(1-\beta)$. Shown in Figure 4.1 is a histogram illustrating the quality index computed from 4 samples from each of 316 lots of P-501 Concrete. These data were taken from recent airport construction projects in the FAA Eastern Region.

The cumulative distribution of the quality index for these 316 lots is shown in Figure 4.2. The procedures used to generate the histogram and cumulative distribution and subsequently pick values for AQL and UQL are given in Chapter 4 for P-501 Concrete. The cumulative distribution is a relationship between the sample population and level of quality index achieved. The tabular listing of the cumulative distribution is presented in Table 4.1. As it turns out, roughly 50% of the values are above 1.2. Use Equation (4-6) to determine that roughly 50% of the lots have an estimated PAL of at least 90. That is,

$$EPAL_4 = 100\ (1-A)$$

$$A = \max\ [0,\ 1/2-1/2Q(n^{1/2}/n-1)]$$

for Q= 1.2 and n = 4

$$A = \max\ [0,.1] = .1$$

$$EPAL_4 = 100(1-A) = 100\ (1-.1)$$

or $EPAL_4 = 90$

This value will serve as the AQL.

TABLE 4.1. CUMULATIVE DISTRIBUTION OF QUALITY INDEX (Q) FOR P-501 CONCRETE

Percentile	Q
99	11.0
95	7.0
90	4.5
80	2.8
70	2.2
60	1.7
50	1.4
40	1.0
30	0.8
20	0.5
10	0.0
5	- 0.5
1	- 1.3

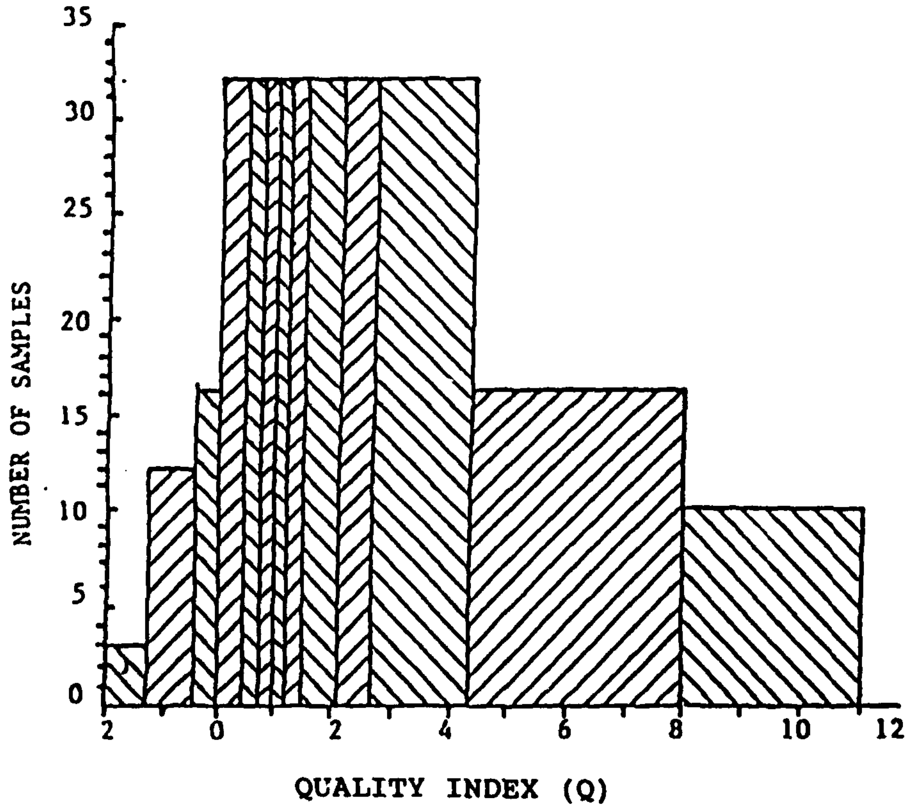


FIGURE 4.1 HISTOGRAM FOR QUALITY INDEX: P-501 CONCRETE

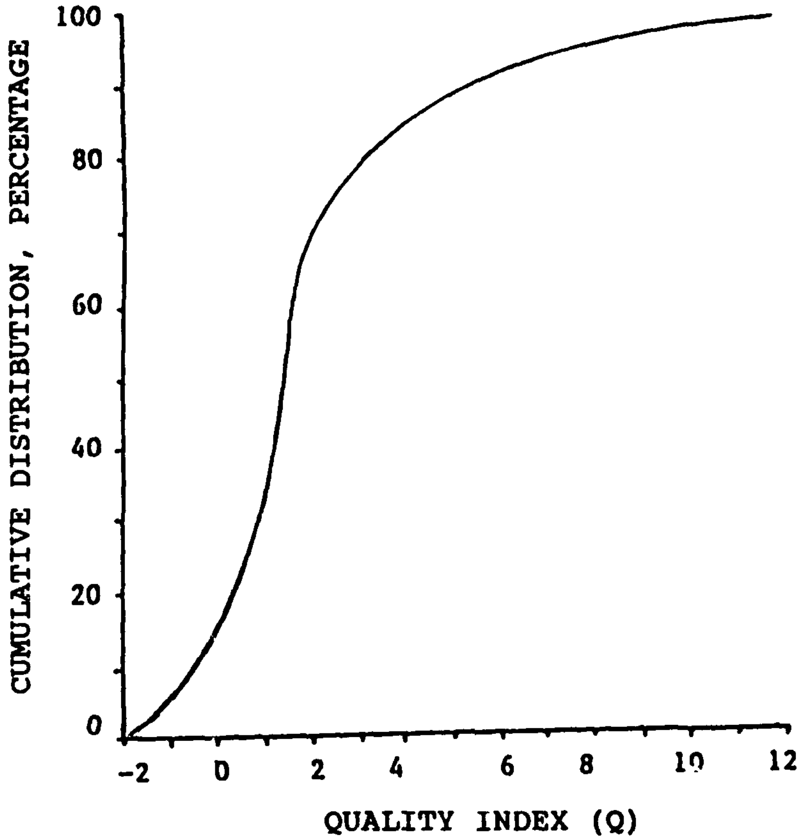


FIGURE 4.2 CUMULATIVE DISTRIBUTION FOR QUALITY INDEX P-501 CONCRETE

The reason for choosing the 50th percentile of the distribution in Table 4.1 is that, assuming the quality control methods for concrete production are generally working and in statistical control, this value is a good estimate of the process mean. Note also that roughly 10% of the values are below a value of Q = .15. Using Equation (4-6), it can be seen that roughly 10% of the lots have an estimated PAL of at most 55. This value is suggested to serve as the UQL; with an AQL of 90 PAL, it is reasonable to expect production to be above 55 PAL.

The acceptance value, as used here, is a value against which the estimated PAL (EPAL) for each lot will be compared. If the EPAL for a lot is above the upper acceptance value, the lot is accepted; if the EPAL for a lot is below the lower acceptance value, the lot is rejected.

In order to compute the acceptance value and lot sample size, it remains to choose α and β. These values can be chosen somewhat arbitrarily, but should be relatively small. Practice has shown that values of α = .05 and β = .10 work well and these values are used here. The acceptance value and lot sample size are calculated using the following procedure from [2]:

$$K = (Z_\alpha Z_2 + Z_\beta Z_1)/(Z_\alpha + Z_\beta), \qquad (4\text{-}15)$$

$$n = (1 + K^2/2)\ [(Z_\alpha + Z_\beta)/(Z_1 - Z_2)]^2, \qquad (4\text{-}16)$$

where,

K = parameter used in calculation of acceptance value,

Z_α = 1-α point of the standard normal distribution,

Z_β = 1-β point of the standard normal distribution,

Z_1 = AQL/100,

Z_2 = UQL/100,

n = lot sample size.

For the case of P-501 Concrete and the results from the foregoing discussion we have:

α = .05, β = 0.10, AQL = 90, and UQL = 55.

As such, from the definitions presented above

$Z_\alpha = 1-\alpha = .95$ $\qquad$ $Z_1 = .90$
$Z_\beta = 1-\beta = .90$ $\qquad$ $Z_2 = .55$,

and from a normal distribution table

$$Z_\alpha = N(.95) = 1.645$$
$$Z_\beta = N(.90) = 1.282$$
$$Z_1 = N(.90) = 1.282$$
$$Z_2 = N(.55) = .1256$$

whereupon, from Equation (4-15)

$$K = \frac{(1.645*.1256 + 1.282*1.282)}{(1.645 + 1.282)} = 0.6321$$

We use Equation (16) to determine the sample size.

$$n = (1+(.6321)^2/2)((1.645+1.282)/(1.282-.1256))^2 = 7.7 \text{ or } 8.$$

Although the values used for the parameters yield a value of sample size n = 8 from Equation (4-16), the values of Q, calculated from the actual construction project data, used sample size n = 4. The implications of this will be discussed later. As it turns out, K is the specific value for the quality index (Q) from all possible values for Q from the sample lots and is used in calculating the expected PAL. For the acceptance value so calculated we can calculate the EPAL using, for this case, Equation (4-10).

$$EPAL_8 = 100(1-10A^3+15A^4 - 6A^5)$$

$$A = \max[0, 1/2 - 1/2Q(n^{1/2}/(n-1))]$$

and here K=Q=.6321 which gives for n=8

$A = .3723$. Then

$$EPAL_8 = 100(1-10*.3723^3+15*.3723^4-6*.3723^5)$$

$$EPAL_8 = 72.92 \text{ or } 73\%$$

Therefore, with an acceptance value of .6321, which implies an $EPAL_8$ of 73%, the consumer can expect to accept lots of 90 PAL about 95% of the time, and the consumer can expect to reject lots of 55 PAL about 90% of the time. The values of AQL = 90 PAL and UQL = 55 PAL are not what the FAA is currently using. These are suggested values for consideration for an increase in product quality.

The operating characteristic (OC), corresponding to a particular level of PAL, is defined as the probability that a lot of the given PAL will be rejected [3]. Consider the suggested acceptance plan for P-501 Concrete. The OC for a lot that is 90 PAL is .05, (α), and the OC for a lot that is 55 is .90, ($1-\beta$). In other words, for lots of 90 PAL, $EPAL_s$ will be less than 73% approximately 5% of the time, just by chance. Likewise, for lots of 55 PAL, $EPAL_s$ will be less than 73% approximately 90% of the time, just by chance. The OC corresponding to other levels of PAL have been calculated and are presented in Table 4.2 and are shown graphically in Figure 4.3. (The procedure is explained in Appendix C).

This information is used in computing the expected payments discussed in the following section. It should be noted that a 90 PAL results in a rejection probability of .044, which is very close to the α = .05 that was specified in the sampling plan. Similarly, a 55 PAL has a rejection probability of .892, which is close to $(1-\beta)$ = .90 specified in the sampling plan. This implies that the acceptance sampling plan, even though the actual sample size is 4, is meeting the desired goals. Thus, the theoretical (calculated) value of sample size from Equation (4-16) may be somewhat conservative.

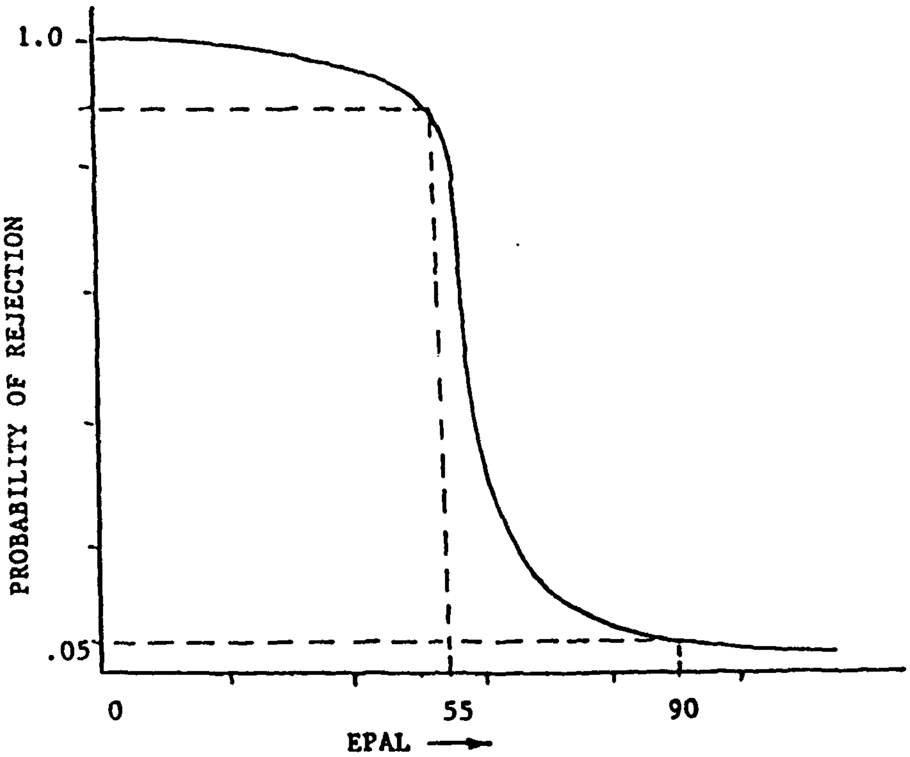


FIGURE 4.3. OPERATING CHARACTERISTIC (OC) CURVE FOR P-501 CONCRETE

TABLE 4.2. OPERATING CHARACTERISTIC (OC) FOR P-501 CONCRETE FOR VARIOUS LEVELS OF PAL

PAL	OC
95	.004
90	.044
85	.140
80	.278
75	.437
70	.589
65	.718
60	.820
55	.892

4.3 Payment Adjustment Schedule

The statistical acceptance plan for P-501 Concrete was developed in the previous section. It was determined that the acceptance plan is to consist of executing the following for each lot in a series of lots: (1) Draw (theoretically) 8 samples, (2) Measure the 28-day flexural strength of each sample, (3) Compute an estimate of lot quality ($EPAL_8$), and (4) Accept or reject the lot, depending on whether the estimate is above or below the acceptance value of Q = .6321. This results in the consumer being assured that on average, 5% of the lots that are at least 90 PAL will be rejected, and that on average, 90% of the lots that are at most 55 PAL will be rejected. This section presents the development of integrated payment schedules for P-401 Asphalt Concrete and P-501 Concrete.

In many situations, the reject decision, as the last step of the statistical acceptance plan, is inappropriate. For example, lots of concrete of less than ideal quality might still have value to the consumer. Furthermore, lots of concrete cost very much to produce and even more to replace. Both considerations imply that the reject decision may not be appropriate or practical. In such cases, it is desirable to have an alternative. A payment adjustment schedule provides an alternative, by introducing a price adjustment system, in lieu of complete rejection.

According to the philosophy of a payment adjustment schedule, for a lot with quality above some upper critical value, the decision is to accept, as before; but for a lot of quality below the upper critical value, the decision is to accept at a reduced price, rather than reject (of course, a lot with quality below some lower critical value is rejected). This allows the consumer to penalize the producer for a lot of less than ideal quality, without having to completely reject the lot. Again, this is particularly important when lots of less than ideal quality have some salvage value and are expensive to replace.

A reasonable payment adjustment schedule is one where the upper critical value is set at the AQL, the lower critical value is set at the UQL, and payment adjustment is based directly on the estimate of lot quality, with lower estimates receiving more severe payment adjustments than those of higher estimates for quality [6].

4.3.1 P-401 Asphalt Concrete, Density

As an example of a payment adjustment plan of the type mentioned above, the statistical acceptance plan and integrated payment adjustment schedule for P-401 Asphalt will be considered. This plan, and corresponding schedule, consists of executing the following for each lot in a series of lots: (1) Draw 4 samples, (2) Measure the density of each sample, (3) Estimate the lot quality using $EPAL_4$, and (4) Make the payment adjustment according to a schedule such as that shown in Table 4.3 [6]. The AQL is assumed to be 90 PAL.[6]

The probability of receiving each of the payment adjustment factors in Table 4.3 (or, equivalently, the probability the estimate will fall into each of the intervals in Table 4.3), given a particular level of PAL, is presented in Table 4.4 [5] for various values of PAL. These probabilities are used to compute the expected payments.

TABLE 4.3. PAY ADJUSTMENT FACTOR FOR P-401 ASPHALT CONCRETE

Interval for Q for Estimate	Payment Adjustment Factor
90-100	1.00
85-89	.98
80-84	.95
75-79	.90
70-74	.80
65-69	.70
0-65	0 or .50

TABLE 4.4. PROBABILITY OF PAY FACTORS FOR P-401 ASPHALT CONCRETE

	Probability of Receiving Given Payment Adjustment Factor							
PAL	1.00	.98	.95	.90	.80	.70	.50	0
50	.048	.015	.022	.031	.043	.059	.587	.195
60	.103	.030	.040	.053	.069	.086	.464	.155
70	.200	.050	.063	.078	.092	.101	.313	.103
80	.358	.072	.084	.092	.095	.089	.189	.021
90	.611	.081	.081	.073	.060	.043	.051	0
98	.914	.037	.025	.014	.007	.003	0	0

The expected payment corresponding to a particular PAL is defined as the average fraction of full pay a producer receives for a series of lots produced at the given PAL [6]. For each level of PAL, the expected payment is calculated by multiplying each payment adjustment factor by the corresponding probability and summing the results. For example, for a series of lots with PAL of 80, the expected payment is (1.00) (.358) + (.98) (.072) + (.95) (.084) + (.90) (.092) + (.80) (.095) + (.70) (.089) + (.50) (.189) + (0) (.021) = .824. Expected payments corresponding to this and other levels of PAL are presented in Table 4.5 [2] for P-401 Asphalt Concrete.

TABLE 4.5. EXPECTED PAY FACTORS FOR P-401 ASPHALT CONCRETE

Lot Quality (PAL)	Expected Payment
98	.992
90	.937
80	.824
70	.680
60	.566
50	.481

Note that the expected payment corresponding to the AQL (90) is equal to .937. This is very close to the $100(1-\alpha)\%$ = 95% that would be theoretically correct. As the PAL falls away from the AQL, the expected payment drops: there is approximately an 18% expected payment decrease for PAL of 80, approximately a 32% expected payment decrease for PAL of 70, and approximately a 43% expected payment decrease for PAL of 60.

4.3.2 P-501, Portland Cement Concrete Pavement, Flexural Strength

A method for creating a pay adjustment factor for P-501 Concrete is presented in the following. The method for establishing an acceptance plan for P-501 Concrete was given in a previous section and the need for a payment plan that provides for the capability to accommodate for pay factors between zero (no pay) and one (full pay) was stated. What remains then is to follow the same path for the acceptance plan for P-501 Concrete, as outlined previously, and state the rationale for choice of relationship between estimate of quality (EPAL) and corresponding pay factor between values of zero and full payment.

As also noted previously, the choice of values for AQL and UQL were made from historical data for P-501 Concrete. This historical data included data from airport construction projects that provided information from over 500 lots of concrete as the source for an estimation of quality for each lot of concrete. As it turned out, some of the information received from the airport construction projects was not admissible as data for quality estimation. Some of this data was from seven and fourteen day cure time specimens. Only data from lots of concrete that satisfied the 28-day cure time and 4 samples from each lot were considered.

Also, data were eliminated from consideration if those data yielded strength values for concrete that were unreasonably different from that considered typical for P-501 Concrete. Consideration of these factors resulted in data from around 316 lots as admissible input to calculate parameters to estimate individual lot quality. These data are the basis for the information shown in Figures 4.1 and 4.2. Again, these data are used to illustrate the procedure that is used to take data from the project file and create the necessary input to generate histograms, cumulative distribution, and suggest values for AQL and UQL.

From these data, the AQL was set at 90 PAL and the UQL value was set at 55. These choices for AQL and UQL are suggested for the sake of improved quality. Use of values for AQL and UQL, currently employed by the FAA to estimate pay factors, will be illustrated in the following discussion. The values for α and β were set at .05 and .10, respectively. The pay factor adjustment to be shown herein was based on four samples from each lot of P-501 Concrete and, strictly speaking, that is inconsistent with the sample size calculated from Equation (4-16). However, it will be shown that use of four samples from each lot to estimate lot quality provides for pay factors that are consistent with the choices for AQL, UQL, α, and β.

There is no universally specified or accepted way to bridge the gap between pay factors of one (full pay) and zero (no pay). Currently, the pay factor for P-501 Concrete is made according to a discrete relationship between pay and two parameters from the flexural tests performed on field specimens from each lot of concrete (See Advisory Circular No. 150/5370-10). The two test parameters are M, modulus of rupture (specified 28-day flexural strength) and R, range of a sample of size n = 4, which is the difference between the largest and smallest test values. We can convert the parameters M and R into equivalent EPAL and state the current pay factor for P-501 Concrete according to:

Pay Factor	Estimated PAL (Based on 28 day Strength, 4 Samples
1.00	$60 \leq$ EPAL
.95	$50 \leq$ EPAL ≤ 59
.85	$43 \leq$ EPAL ≤ 49
.75	$37 \leq$ EPAL ≤ 42
.50	EPAL ≤ 36

This discrete relationship between EPAL and Pay Factor for P-501 Concrete, currently in use by the FAA, is graphically shown in Figure 4.4. The discrete nature of this relationship presents the obvious dilemma, equal pay factor for less quality product. That is, if the value for EPAL is, say, 49 for a given lot of concrete and the value for EPAL for another lot of concrete is 44, then the pay factor is, from Figure 4.4, the same for both lots, namely 85% of full pay.

It is desirable to have a unique value of pay factor for each value of EPAL between pay factors of one and zero. Thus, a continuous relationship between pay factor and EPAL should be established for values of pay factor between one and zero. As mentioned in the beginning of Section 4.3, the shape of the functional relationship between pay factor and EPAL should be such that higher pay factors should be associated with higher quality and lower pay factors associated with lower quality. As such, the slope of the curve (functional relationship between pay factor and EPAL) should be mild, or less steep, as pay factor is reduced from one. Further, reduction in a value of EPAL should be reflected in a steeper slope in the curve that represents the functional relationship between pay factor and EPAL. These are the basic thoughts that went into the establishment of the pay factor for P-501 Concrete from this work.

A brief discussion follows that illustrates how the functional relationship between pay factor and EPAL for values of pay between one and zero can be established. It was also mentioned before that the values for AQL and UQL should be and were derived from historical data. In the case of P-501 Concrete this amounted to examination of data from 316 lots of concrete from past and ongoing airport construction projects. If the relationship between pay factor and EPAL is thought of as analogous to a plot of x vs. y, two points in x, y space can be defined immediately; namely, pay factor equal to one and EPAL equal to AQL - call this point (x_1, y_1) and pay factor equal to zero (or some agreed on minimum payment) and EPAL equal to UQL - call this point (X_2, y_2). This is illustrated in Figure 4.5.

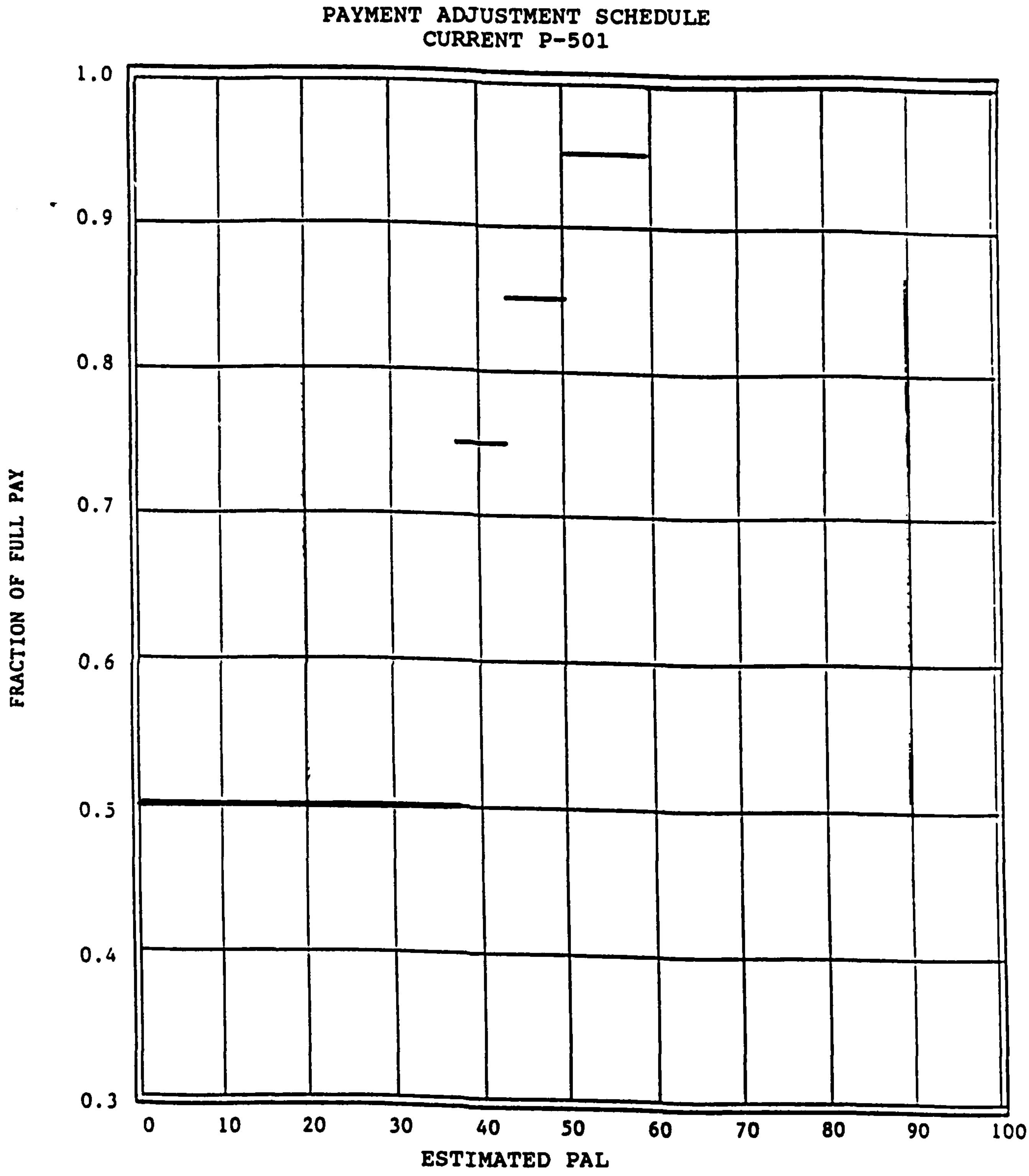


FIGURE 4.4 PAY FACTOR FOR P-501 CONCRETE CURRENTLY IN USE BY FAA

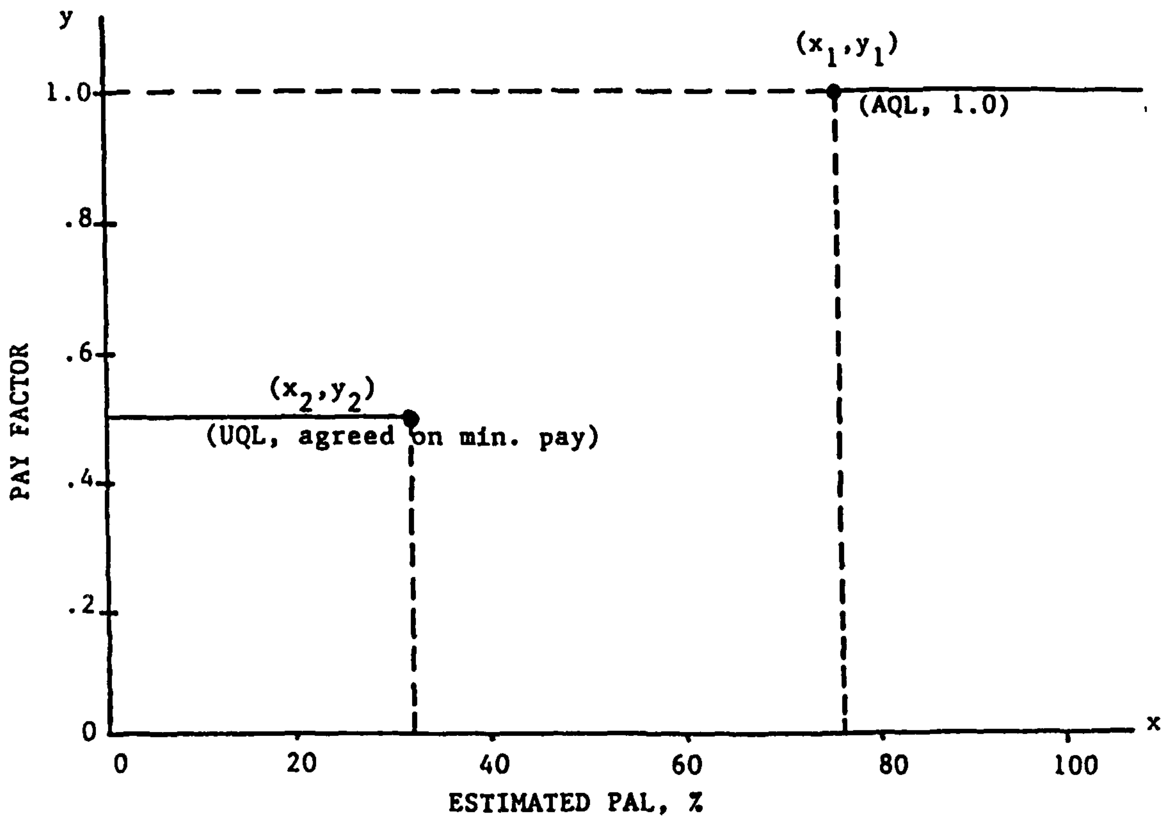


FIGURE 4.5. DEFINITION OF AQL, UQL, AND PAY FACTOR IN TERMS OF x AND y

The task is to bridge the gap between the two points (x_1, y_1) and (x_2, y_2). A quadratic function (second degree in power of x) was selected such that the slope of the curve is gradual, when moving away from point (x_1, y_1) to the left. The slope of the function is quite steep, as the curve joins point (x_2, y_2) from the right. The equations that describe this type of behavior follow and Figure 4.6 is helpful in explaining the parameters involved.

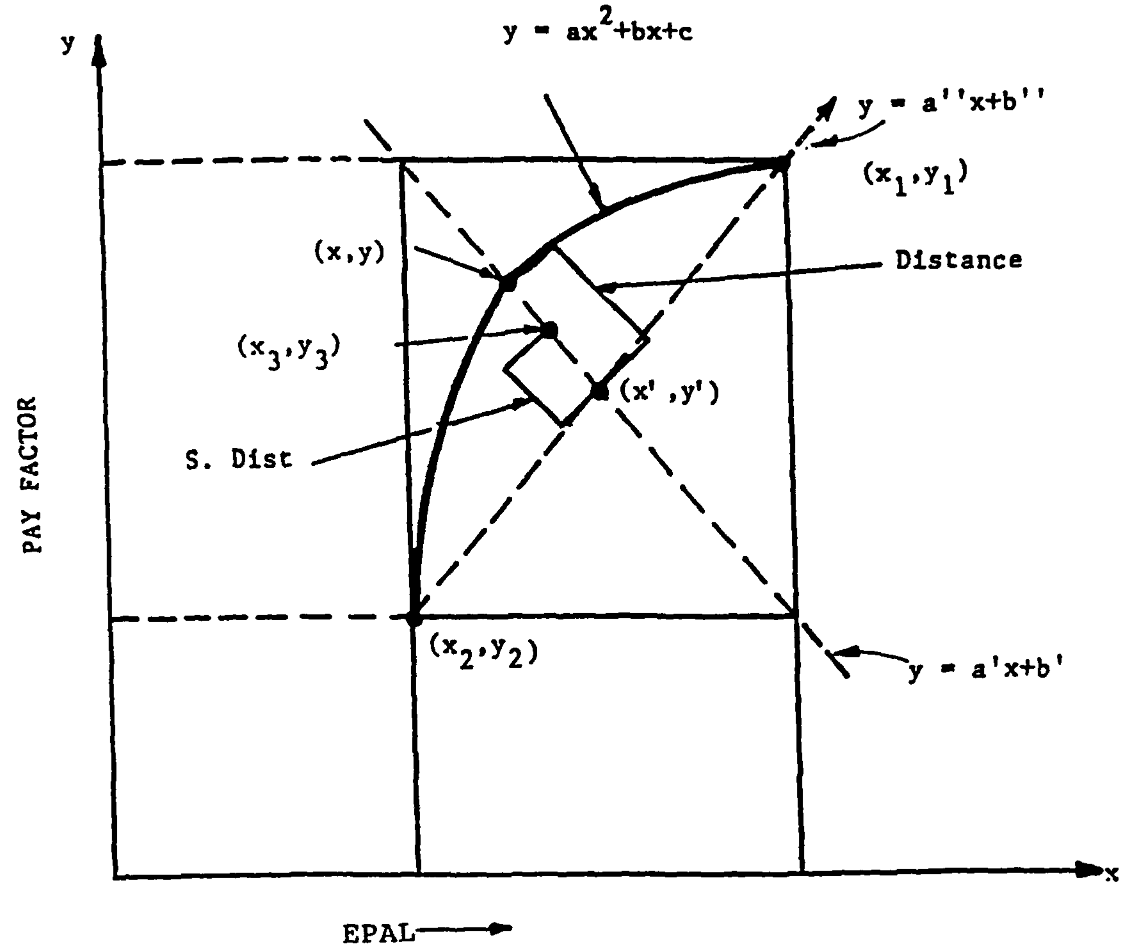


FIGURE 4.6. PAY FACTOR VS. EPAL BETWEEN VALUES OF AQL AND UQL

A few words concerning the parameters involved in generating the function between points (x_2, y_2) and (x_1, y_1) are worthwhile. The straight line joining (x_2, y_2) and (x_1, y_1) in Figure 4.7 can be thought of as a limiting curve (clearly the simplest) to bridge the gap. In fact, any function or curve to the right of this line would punish the producer of higher quality work more than the producer of lower quality work. Consistent with this is the distance from the point (x', y_2') on the straight line to the general quadratic form, $y = ax^2 + bx + c$, at (x,y). The distance in this direction is considered positive.

The S-Dist is a fraction of the distance from the straight line and the general quadration function. The end points of the S-Dist are (x', y') and (x_3, y_3). Thus, the limiting curves (for nonnegative values of distance) are the straight line and the general function $y = ax^2 + bx + c$. When S-Dist = 0, the curve is the straight line and when S-Dist = Distance, the curve is the general quadratic. The following formulas have been used to define the parameters used in the quadratic function between points (x_1, y_1) and (x_2, y_2).

$$a = \frac{y_2 - y_1}{x_2^2 - 2x_2x_1 + x_1^2} \;;\; b = -2x_1a \;;\; C = x_1^2a + y_1$$

$$a' = \frac{y_1 - y_2}{x_2 - x_1} \;;\; b' = -x_1a' + y_2$$

$$a'' = \frac{y_1 - y_2}{x_1 - x_2} \;;\; b'' = -x_2a'' + y_2$$

$$x = (a' - b) + [(b-a')^2 - 4a(c-b')]^{1/2} ; y = a'x' + b'$$

$$x' = \left(\frac{b''-b'}{a'-a''}\right) \;;\; y' = a''x + b''$$

$$\text{Distance} = [(x' - x)^2 + (y'-y)^2]^{1/2}$$

$$x_3 = x' - (\text{S-Dist})\cos[\tan^{-1}(y_3-y_2)/(x_3-x_2)]$$

$$y_3 = a'x_3 + b'$$

The advantage of this technique is that it is flexible enough to handle most conditions that can be practically implemented as far as pay factors are concerned. AQL and maximum pay factor equal to one are the coordinates for (x_1, y_1) and UQL and minimum pay factor are the coordinates for (x_2, y_2). Calculations of distance dictates how severe producers of poorer quality will be penalized for quality between AQL and UQL.

This method was applied to the current P-501 Concrete pay factor where AQL = 59% and UQL = 37%. The graphical results are shown in Figure 4.7. Also superposed in Figure 4.7 are the discrete values of pay factor according to what is currently in use. The distance parameter in Figure 4.7 was chosen so as to obtain close to average values for pay factor between the various discrete range values.

If we now consider the values of AQL = 90 PAL and UQL = 60 PAL that is close to the values previously generated from the historical data base for P-501 Concrete and choose a value for S-Dist = 0.6, the following quadratic function is generated.

$$\text{Pay Factor} = -3.212 * \text{EPAL}^2 + 6.4347 * \text{EPAL} - 2.235$$

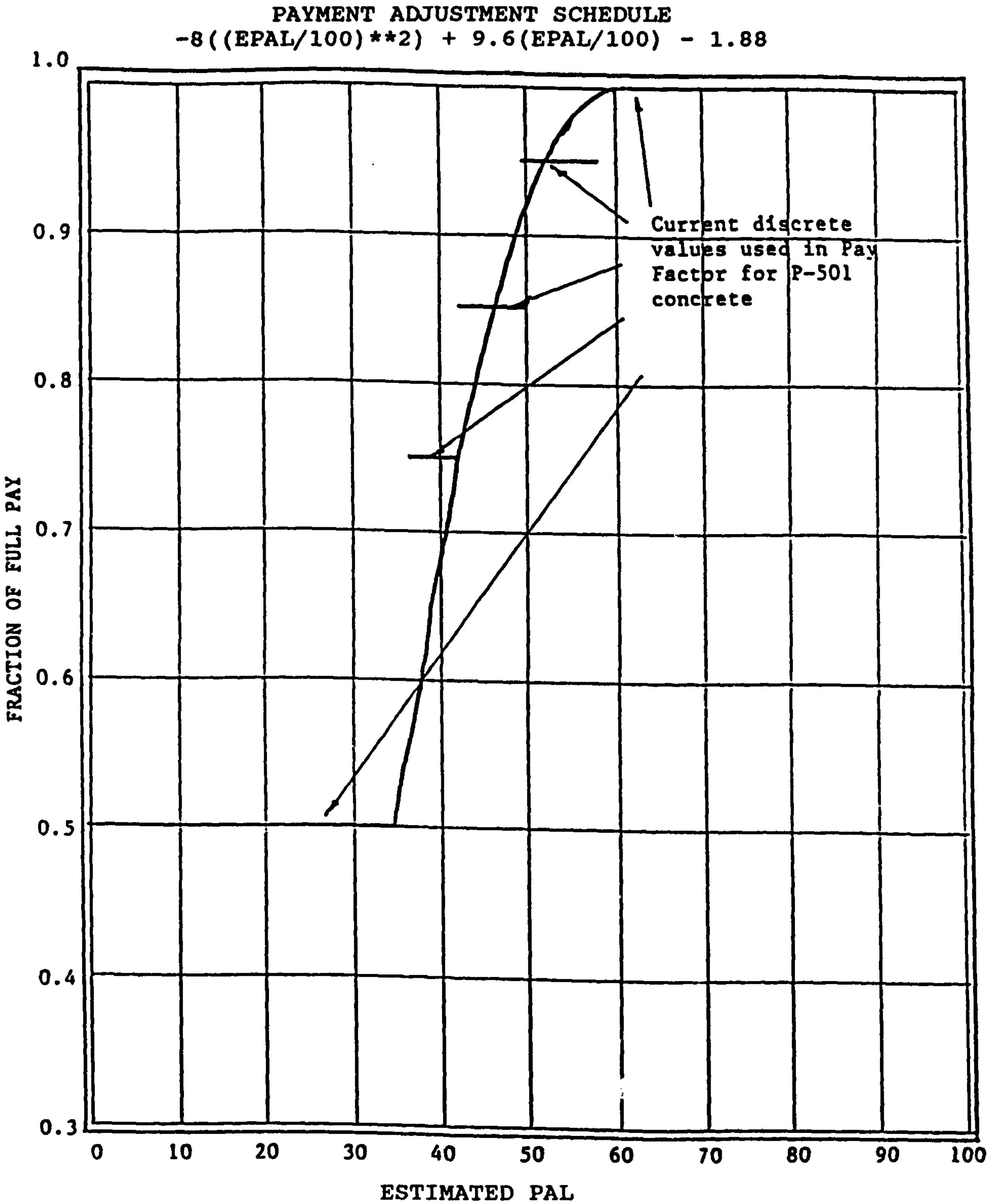


FIGURE 4.7 APPLICATION OF METHODOLOGY TO CURRENTLY USED VALUES OF AQL AND UQL FOR P-501 CONCRETE

This pay factor, as a function of EPAL, is shown in Figure 4.8. Therein, we have arbitrarily set pay factor = 0 if EPAL <60%. But again, the flexibility in the method should be noted, since a broad range of values can be selected for AQL, UQL, S-Dist, and minimum pay, depending on how severe the punishment for poor quality should be.

The foregoing has shown that a payment adjustment schedule can be successfully integrated with a statistical acceptance plan by first following the well-known procedure for developing a statistical acceptance plan. The plan can be used as a basis for the payment adjustment schedule, that assigns a payment adjustment to an individual lot.

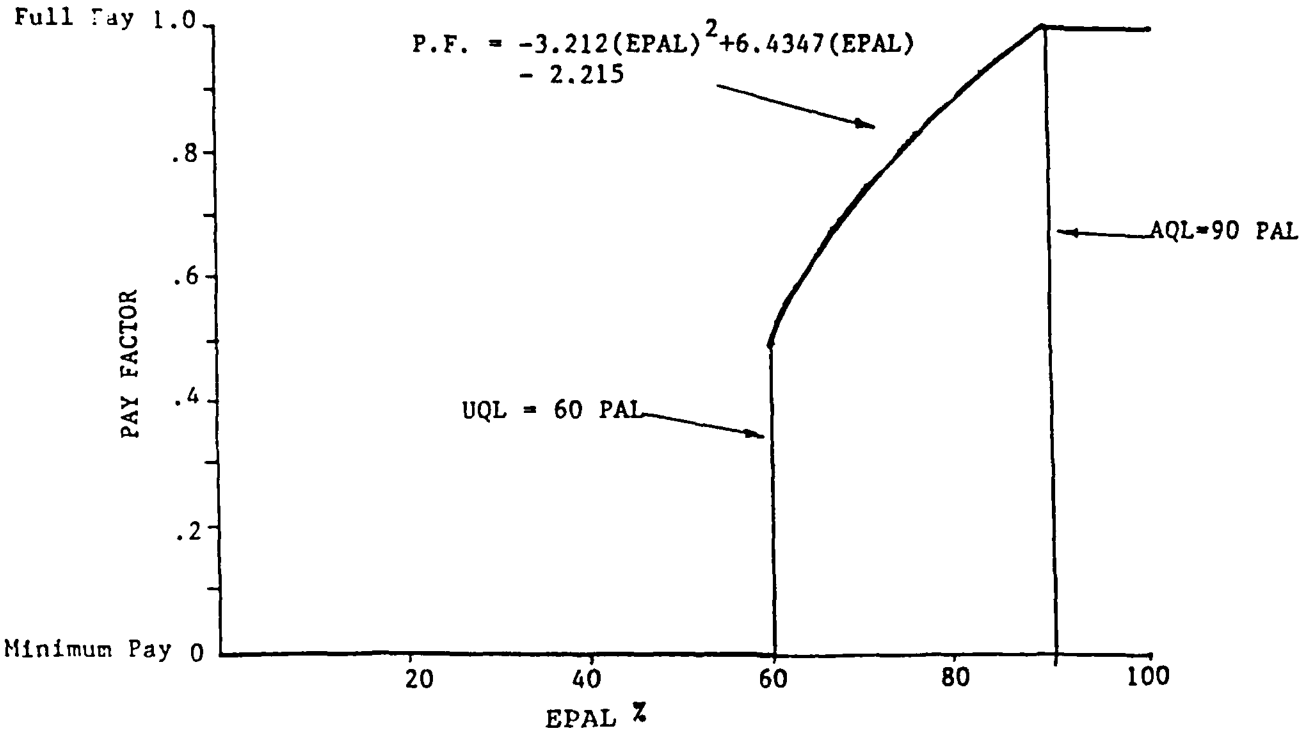


FIGURE 4.8. APPLICATION OF METHODOLOGY FOR P-501 CONCRETE USING VALUES OF AQL AND UQL DERIVED FROM HISTORICAL DATA

In the following subsections the applicability of the methodology to the other material specifications P-152, Excavation and Embankment, Density; P-209, Crushed Aggregate Base Course, Density; P-304, Cement Treated Base Course, Density; P-306, Econocrete Subbase Course, Density; and P-501, Portland Cement Concrete Pavement, Thickness will be discussed.

4.3.3 P-152, Excavation and Embankment, Density

During data collection interviews involving contractor personnel and FAA field personnel, airport personnel and consulting engineers, it was apparent that most engineering monitors preferred a construction contractor to continue to rework and reroll this material until a "pass" was obtained from the "pass/fail" tests, rather than offer a payment adjustment for the section for which the tests failed.

This situation was consistent with that discovered by the FAA in interviews with pavement industry personnel and field engineers. As such, it was mutually agreed that further development of a statistically based pay adjustment plan be suspended, because changing from the current method of testing will be resisted by those required to use it.

4.3.4 P-209, Crushed Aggregate Base Course, Density

It was mutually agreed that no further effort be made to develop a pay adjustment plan for this item for the same reasons stated in Subsection 4.3.3.

4.3.5 P-304, Concrete Treated Base Course, Density

Sufficient pavement material test data were not available in the FAA Eastern Region for this item to develop a statistically based pay adjustment schedule. A significant amount of effort was spent by the contractor in the attempt to locate this data.

It was mutually agreed that since there is no guarantee that meaningful data would result from any other FAA region for this item, no further attempt would be made to acquire data for P-304. For this reason, and the reasons explained in Subsection 4.3.3, there would be no requirement to develop a pay adjustment factor for P-304, Concrete Treated Base Course, density.

4.3.6 P-306, Econocrete Subbase Course, Density

For the exact reasons stated in Subsection 4.3.5, it was agreed not to develop a pay adjustment for the density specification for P-306 Econocrete. However, the current FAA specification for P-306 Econocrete involves a pay adjustment for the item based on thickness, with limitations placed on slump, air content and compressive strength. It was agreed that since compressive strength for P-306 Econocrete is monitored in almost the same manner as that for P-501 Concrete flexural strength, a pay factor for P-306 Econocrete, based on compressive strength, could be accomplished with the data on hand. This effort was undertaken and the results are included in a later chapter.

4.3.7 P-501, Portland Cement Concrete Pavement, Thickness

Sufficient pavement material test data were not available in the FAA Eastern Region to be able to develop a pay adjustment schedule for this item. This is because, as was discovered during the data collection attempt, most engineers monitoring this item approve thickness by measuring concrete form depth instead of requiring destructive thickness core tests.

It was mutually agreed that because there was not a guarantee for any improvement in the collection of core test data for this item from any other FAA region, no additional effort should be put forth to collect such data and as such, no pay adjustment factor for P-501, Portland Cement Concrete Pavement, thickness would be required.

5. USE OF PROJECT DATA TO GENERATE AQL AND UQL FOR P-501 CONCRETE

5.1 Need for AQL and UQL for P-501 Concrete

In the discussions contained in Chapters 3 and 4, Acceptable Quality Limit (AQL) and Unacceptable Quality Limit (UQL) were defined and hints were given as to the choice of values for these two parameters; these are key ingredients in the establishment of integrated acceptance and pay adjustment plans. Recall in Chapter 3, the histogram for Quality from P-501 Concrete flexural strength test values from past airport construction projects was presented in Figure 4.1. Also, the corresponding cumulative distribution of Quality for those projects was presented in Figure 4.2. In the discussion that involved Figures 4.1 and 4.2, values for choices of AQL and UQL were stated.

The intent of the material presented in this chapter is to justify and explain how the choice for those values is made. The explanation that follows will present the procedure that can be used to gain insight into the choice of values for AQL and UQL and as such the initial values for AQL and UQL so derived may be just that, initial values. Final values may include an iterative process wherein the pay factors are generated using the initial values of AQL and UQL and the resulting curve that bridges the gap from AQL to UQL.

These pay factors can then be compared with what appears reasonable, as far as pay penalty applied to the contractor is concerned. That is, does the initial choice of AQL and UQL result in pay factors that are too harsh or too lenient? If so, then a second choice for values of AQL and UQL can be made and the procedure repeated until the resulting pay factors are consistent with what the agency feels represents the required level of quality needed at the project site and at the same time is an attainable level that can be achieved by the contractor for an acceptable cost.

To aid in this procedure, simple computer programs have been written and the use of these programs will be detailed in the material which follows. Specifically, there are two such computer programs. One creates a data base, and the second uses this data base together with a statistical analysis package, SAS, which generates the information upon which the decision for initial choice of AQL and UQL is made.

5.2 Computer Programs to Combine Field Test Values into Data Base

The first activity that must be performed after data have been received from various construction projects is to create a data base which contains test values for the attributes that are estimated to measure quality for the construction material of interest.

In this effort, the material was P-501 Concrete and the attribute was flexural strength. The program outlined in this sub-section allows data to be added to an existing data base or generate entirely new data by replacing the old data with the new data. The program is written in dBASE III. During this effort, the data would only be admissible to the data base if the test results were from 28-day cured test specimens.

5.2.1 Program Description 'JOIN'

This dBASE III program is called 'JOIN' and must be executed to combine all the data base files (construction project information) together and generate an ASCII file which will be used by the SAS program. The 'JOIN' program requires all data base files to include four common fields, otherwise the program will not execute. These fields are:

1. AGE: Age of the sample (program will elect records with AGE=28).
2. TEST DATE: Date when test was performed.
3. STR: Strength of the tested sample.
4. LOT NO: Lot identification number.

To run the program at the DOS prompt type:
(Do not type the ' ' around JOIN)

'JOIN' and press <enter>

1. If the (existing) combined data base contains data from a previous execution, the user is asked:

   'JOIN.DBF file already contains some data .....'
   'Please enter <D> or <A> ? (D/A) ---->'

   Responding:'D' will delete all the data in the combined file
   Responding:'A' will add new data to the file keeping the old data.

2. The user will then be asked the following question:

   'ENTER THE FILE NAME (? TO STOP) ------>'

Entering: '?' will go to step 3
Entering: 'any' file name', disk is searched for the specified file name.
If found: test date, strength and lot number are copied from the specified file name to the combined file.
not found: user is prompted:

'FILE NAME DOES NOT EXIST, PLEASE RE-ENTER...'

3. The user will be asked the following question:

'Do you wish to create an ASCII File? (Y/N) -->'

Responding: 'Y' will create an ASCII file called 'JOIN.TXT' which will be used by the SAS program; process is then terminated.
Responding: 'N' will not create an ASCII file, process is then terminated.

'JOIN' PROGRAM LISTING

***Program name: Join**
***Description:** This program combines several data files together

```
CLEAR
SET TALK OFF
STORE .T. TO CONT
SELE 1
USE JOIN
*-------------------------------------------------------------*
*  FOLLOWING LOOP WILL CHECK PRIOR TO EXECUTION OF THE PROGRAM *
*  IF ANY DATA ALREADY EXISTS IN THE JOIN.DBF FILE.  IF ANY    *
*  FOUND THE USER IS ASKED WHETHER THEY WISH TO DELETE THE     *
*  ALREADY EXISTING DATA IN THE FILE OR APPEND TO IT.          *
*-------------------------------------------------------------*
IF .NOT. EOF()
   DO WHILE CONT
   STORE ' ' TO ANS
   @ 1,1 SAY 'JOIN.DBF file already contains some data ....'
   @ 3,1 SAY 'Please enter <D>elete or <A>ppend ? (D/A)---->'
   @ 3,49 GET ANS
   READ
   IF UPPER(ANS)='D' .OR. UPPER (ANS)='A'
      STORE .F. TO CONT
      LOOP
   ENDIF
   ENDDO
   IF UPPER(ANS) = 'D'
      ZAP
   ENDIF
ENDIF
```

```
*****************************************************************
*  FOLLOWING LOOP WILL ASK THE USER FOR THE FILE NAME TO BE     *
*  INCLUDED IN THE JOIN.DBF FILE.  IF FOUND THE FOLLOWING THREE*
*  FIELDS ARE COPIED TO THE JOIN.DBF:                           *
*                                                               *
*  AGE:        AGE OF THE SAMPLE (THIS PROGRAM SEARCHES FOR THE *
*              28 DAY TESTS.                                    *
*  TEST DATE: TEST DATE, WHEN THE TEST WAS PERFORMED            *
*  STR:        STRENGTH OF THE MATERIAL                         *
*  LOTNO:      LOT NUMBER THE TEST WAS DONE                     *
*                                                               *
*  NOTE: ..........ALL FILES MUST HAVE AT THE MINIMUM ALL THE  *
*                  ABOVE MENTIONED DATA ELEMENTS                *
*---------------------------------------------------------------*
CLEAR
STORE .T. TO CONT
DO WHILE CONT
   STORE '          ' TO NAME
   @ 1,1 SAY 'ENTER THE FILE NAME (? TO STOP) ----->'
    @ 1,40 GET NAME
    READ
    IF NAME='?
    STORE .F. TO CONT
    LOOP
    ENDIF
    STORE NAME+'.DBF' TO FNAME
    IF .NOT. FILE (FNAME) THEN
       @  20,1  SAY  'FILE  NAME  DOES  NOT  EXIST,  PLEASE  RE-
ENTER........'
       WAIT
       CLEAR
       LOOP
ENDIF
SELE 2
USE & NAME
LOCATE FOR AGE = 28
DO WHILE .NOT. EOF()
   SELE 1
```

```
   APPEND BLANK
   REPLACE TESTDATE WITH B->TESTDATE
   REPLACE STR WITH B-?STR
   REPLACE LOTNO WITH UPPER(LOTNO)
   SELE 2
   CONTINUE
  ENDDO
ENDDO
CLOSE ALL
*----------------------------------------------------------*
*  FOLLOWING LOOP WILL ASK THE USER IF HE WISHES TO CREATE AN *
*  ASCII FILE FROM THE COMBINED DATA SET.  IF 'YES' A FILE    *
*  CALLED 'JOIN.TXT' WILL BE CREATED                          *
*----------------------------------------------------------*
CLEAR
USE JOIN
STORE .T. TO CONT
IF .NOT. EOF()
   DO WHILE CONT
   STORE ' ' TO ANS
   @ 1,1 SAY 'Do you wish to create a ASCII file? (Y/N) --->'
   @ 1,49 GET ANS
   READ
   IF UPPER (ANS)='Y' .OR. UPPER(ANS)='N'
      STORE .F. TO CONT
      LOOP
   ENDIF
ENDDO
IF UPPER(ANS) ='Y'
   IF FILE(JOIN.TXT) THEN
      DELETE FILE JOIN.TXT
   ENDIF
   COPY TO JOIN.TXT SDF DELIMITTED WITH BLANK
 ENDIF
ENDIF
```

Once the data base has been created, the data is manipulated and statistically analyzed to provide the information based on which the initial choice for values of AQL and UQL is made. Following is a listing of the program which uses the data base and invokes SAS to analyze the data. Also, a sample of the output from the program that has used the P-501 Concrete flexural strength information is given and discussed.

5.2.2 Program Description 'SAS P-501'

The SAS program in this section illustrates how the P-501 Concrete flexural strength data was screened and how the remaining admissible data was used to determine values for AQL and UQL. The SAS program given herein can be easily modified to meet the specific format of the input ASCII data set. As mentioned in the previous subsection, only 28-day strength data was present in the ASCII data set and, therefore, only this type of data was in the input file P-501.DAT. If this would happen not to be the case, SAS can easily subset the data as needed based on an additional input variable, e.g., AGE.

The SAS program in file P501.SAS can be run in the batch mode by typing the following:

```
SAS P501
or
SAS P501.SAS
```

This will create two output files - P501.LOG (contains SAS input statements from P501.SAS with any error messages) and P501.LST that contains the desired output. After this batch SAS job has been completed, print P501.LST. The output should be examined carefully to determine the screening criteria (if different than what is specified in P501.SAS). If different screening criteria are desired, modify P501.SAS accordingly and run the SAS P501 program a second time using the above commands, e.g., SAS P501.

The SAS program can be run interactively using the SAS Display Manager. To do this, enter SAS at the DOS prompt. SAS will then show the Display Manager on the terminal screen. In the Program Editor portion of the 3 window screen Display Manager, enter the following at the Command line prompt:

```
INCLUDE "P501.SAS"
```

To execute the program, press Function Key F10. This will submit the program. The program output will be displayed in the OUTPUT window. To save this output for future viewing and printing, enter the following at the command line prompt within the OUTPUT window:

```
FILE "P501.LST"
```

This creates the ASCII file "P501.LST" that can then be printed out with the DOS command PRINT. For example, enter the following at the DOS prompt once you have exited from SAS:

```
PRINT P501.LST
```

Below is a listing of the contents of P501.SAS. The items highlighted with an asterisk are those that one may need to modify or adapt this program to meet his specific needs.

The names that follow, with underlines as spaces, such as LOT_NO, MEAN_STR, N_STR, STD_STR, and Q_STR are varible string file names and can also be found in Tables 5.1, 5.2, 5.3, and 5.4 and Figures 5.1 and 5.2.

```
TITLE "Determination of AQL and UQL using P-501 data";
TITLE2 "Performed on lots of 28 day strength";
TITLE3 "Lots with >= 4 samples";
OPTIONS PAGESIZE=62;
* INPUT FILE SHOULD CONTAIN THE 3 VARIABLES BELOW;
* ADDITIONAL VARIABLES MAY BE ADDED AS NEEDED;
DATA ONE;
     INFILE "P501.DAT";
        INPUT TESTDATE 1-8 STRENGTH 10-12 LOT_NO $ 14-20;
PROC SORT;
    BY TESTDATE LOT_NO;
*BELOW PROC MEANS CREATES DATASET WITH LOT MEANS;
PROC MEANS NOPRINT MEAN STD N;
   OUTPUT OUT = TWO MEAN = MEAN_STR N = N_STR STD = STD_STR;
    VAR STRENGTH;  BY TESTDATE LOT_NO;
* BELOW SELECTS ONLY LOTS WITH >= 4 SAMPLES;
DATA THREE; SET TWO; IF N_STR >= 4;
* IF THE ACCEPTANCE CRITERIA CHANGE, 650 BELOW MAY NEED TO BE
MODIFIED;
  Q_STR = (MEAN_STR - 650)/STD_STR;
PROC SORT; BY MEAN_STR;
PROC PRINT;
      VAR TESTDATE LOT_NO N_STR MEAN_STR STD_STR Q_STR;
/* USE THIS PRINTOUT TO SCREEN DATA BASED ON MEAN */;
*BELOW ARE SAMPLE SCREENING CRITERIA FOR MEAN;
DATA FOUR; SET THREE; IF MEAN_STR > 500 AND MEAN_STR <1200;
PROC SORT; BY Q_STR;
PROC PRINT;
      VAR TESTDATE LOT_NO N_STR MEAN_STR STD_STR Q_STR;
/* USE THIS PRINTOUT TO SCREEN DATA BASED ON Q_STR */;
* BELOW ARE SAMPLE SCREENING CRITERIA FOR Q;
DATA FIVE; SET FOUR ; IF Q_STR > -3 AND Q_STR < 10;
*STATEMENTS BELOW SUMMARIZE SELECTED DATA;
* THIS OUTPUT SHOULD BE CLOSELY EXAMINED TO PICK THE AQL AND UQL;
PROC UNIVARIATE; VAR MEAN_STR Q_STR;
PROC CHART; HBAR MEAN_STR / MIDPOINTS = 550 TO 1000 BY 25;
PROC CHART; HBAR Q_STR / MIDPOINTS = 01 TO 05 BY .5;
RUN;
```

5.2.3 Sample Output

Shown in Tables 5.1, 5.2, 5.3, and 5.4 are sample outputs from running the program listed above. Table 5.1 displays the data arranged so that the calculated values of mean per lot are in ascending order. A lot is defined in this example as consisting of data from the same date and same project location. Also in these output samples, if the number of test values for a lot is less than 4, the lot was not admitted.

The data records recieved during the data collection had not made any distinction between the number of tests that constitute a lot, so it was determined to assign samples to a specific lot number for the same day. This is only for the previously collected data and should not apply to techniques in general and of future data. Hopefully, future test samples per lot will be somewhere between three and six. As such, the minimum number of tests in Column 4 of Table 5.1 is 4 and, as it turns out, the maximum number of test values is 28. Thus, the mean value for flexural strength per lot range from a minimum value of 105.2 psi to maximum value of 934.5 psi is as shown in Table 5.1.

The values for quality index, (Q), are listed in Table 5.2 in ascending order. The same restriction on minimum number of test values per lot (4), of course, is applied to the listing in Table 5.2. As can be seen in the program listing, the lower specification limit of 650 psi has been used in the calculation of Q listed in Table 5.2. This lower limit value may need to be modified for other/later applications. The values of Q listed in Table 5.2 are also restricted to values of the mean calculated and listed in Table 5.1 to be between 500 psi and 1200 psi. Correspondingly, the values of Q in Table 5.2 range from -2.927 to 59.273.

Table 5.3 lists the results of applying a univariate procedure to the values of the mean per lot between the limits of 500 psi and 1200 psi. Therein are the values for the parameters calculated from this procedure. The mean value and standard deviation for the population of test values for flexural strength, as determined from applying the above mentioned restrictions to the data base, are easily obtained from the listing in Table 5.3, as are other useful items such as 50% percentile, range, etc.

Similarly, Table 5.4 lists the results of applying a univariant procedure to values of Q listed per lot in Table 5.2.

Finally, shown in Figures 5.1 and 5.2 are the histograms for mean value of flexural strength and quality index, (Q), respectively. The histogram for mean value, Figure 5.1, indicates that the distribution of mean value is insignificantly different from normal. Therein about 50% of the values for mean value are above 750 psi.

TABLE 5.1
MEAN VALUES OF FLEXURAL STRENGTH FOR P-501 CONCRETE
FROM PROJECT TEST SPECIMENS

OBS	TESTDATE	LOT_NO	N_STR	MEAN_STR	STD_STR	Q_STR
1	19860925	BUF501	5	105.200	4.550	-119.743
2	19860909	BUF501	4	107.250	2.217	-244.774
3	19850915	SBY501	6	109.333	6.282	-86.063
4	19850917	SBY501	9	109.333	5.244	-103.101
5	19860716	BUF501	8	116.125	12.194	-43.781
6	19860729	BUF501	6	117.667	9.180	-57.990
7	19850914	SBY501	4	126.750	9.912	-52.789
8	19851001	ACY501A	10	542.800	149.999	-0.715
9	19850930	ACY501A	8	552.750	33.225	-2.927
10	19850924	ACY501A	6	591.167	43.116	-1.365
11	19850730	PHL501A	6	600.500	74.675	-0.663
12	19850722	PHL501A	8	622.875	63.623	-0.426
13	19850807	PHL501A	8	637.500	56.609	-0.221
14	19860725	IAD501A	6	637.500	49.066	-0.255
15	19860808	BUF501A	16	645.312	35.752	-0.131
16	19800802	SYR501A	4	646.500	24.826	-0.141
17	19860815	BUF501A	4	648.750	57.355	-0.022
18	19860607	IAD501A	4	656.250	26.575	0.235
19	19860627	IAD501A	24	657.917	36.083	0.219
20	19860722	IAD501A	6	661.667	35.166	0.332
21	19800708	SYR501A	4	667.000	0.000	.
22	19800502	SYR501A	4	668.750	6.292	2.980
23	19860819	BUF501A	12	668.750	67.086	0.279
24	19851002	ACY501A	9	669.111	97.308	0.196
25	19840706	ORF501B	4	670.000	97.211	0.206
26	19800711	SYR501A	4	676.500	21.000	1.262
27	19850802	PHL501A	6	680.333	72.152	0.420
28	19860605	IAD501A	10	680.500	46.335	0.658
29	19860623	IAD501A	26	681.038	34.106	0.910
30	19860625	IAD501A	23	681.304	62.599	0.500
31	19860626	IAD501A	24	682.292	50.021	0.646
32	19800422	SYR501A	4	685.000	19.149	1.828
33	19850717	PHL501A	12	685.167	42.861	0.820
34	19840714	ORF501B	4	686.250	161.729	0.224
35	19850723	PHL501A	8	686.250	77.076	0.470
36	19850925	ACY501A	11	686.818	72.057	0.511
37	19800709	SYR501A	4	687.500	23.671	1.584
38	19860731	BUF501A	14	687.500	101.787	0.368
39	19850806	PHL501A	8	688.375	46.965	0.817
40	19850815	PHL501A	8	689.375	71.496	0.551
41	19001008	PIT501A	6	694.500	108.614	0.410
42	19860718	PIT501C	6	698.500	51.458	0.943
43	19800424	SYR501A	4	701.250	37.500	1.367
44	19850809	PHL501A	8	701.625	56.840	0.908
45	19860606	IAD501A	12	702.083	69.885	0.745
46	19860825	BUF501A	8	702.500	57.321	0.916
47	19850719	PHL501A	6	703.500	74.167	0.721
48	19860804	BUF501A	12	703.750	95.134	0.565
49	19850801	PHL501A	8	705.375	104.125	0.532
50	19840711	ORF501B	4	707.500	68.860	0.835
51	19860725	BUF501A	15	710.133	120.997	0.497
52	19800529	SYR501A	4	710.250	10.532	5.721
53	19860610	IAD501A	28	710.536	47.324	1.279
54	19860812	BUF501A	16	712.187	57.095	1.089
55	19860905	PIT501C	8	714.500	64.398	1.002

TABLE 5.1 (CONTINUED)
MEAN VALUES OF FLEXURAL STRENGTH FOR P-501 CONCRETE
FROM PROJECT TEST SPECIMENS

OBS	TESTDATE	LOT_NO	N_STR	MEAN_STR	STD_STR	Q_STR
55	19860926	BUF501A	6	716.667	28.225	2.36195
57	19800803	SYR501A	4	718.750	52.519	1.30905
58	19800430	SYR501A	4	720.000	60.000	1.16667
59	19840712	ORF501B	4	721.250	56.624	1.25831
60	19860903	BUF501A	5	723.000	55.969	1.30430
61	19850627	PHL501A	6	723.167	44.638	1.63911
62	19850718	PHL501A	8	724.250	78.640	0.94419
63	19850815	ACY501A	6	724.500	150.488	0.49506
64	19860904	BUF501A	18	726.389	92.495	0.82587
65	19860902	BUF501A	24	726.458	98.063	0.77969
66	19800702	SYR501A	4	729.000	24.249	3.25791
67	19860829	BUF501A	8	733.125	46.209	1.79889
68	19860820	BUF501A	12	733.333	78.432	1.06250
69	19850724	PHL501A	8	733.500	64.029	1.30410
70	19840625	ORF501B	4	735.000	27.988	3.03701
71	19000922	PIT501A	4	737.500	30.838	2.83738
72	19800605	SYR501A	4	739.000	39.345	2.26206
73	19800602	SYR501A	4	739.500	21.000	4.26190
74	19800703	SYR501A	4	739.500	21.000	4.26190
75	19800905	SYR501A	4	739.750	62.612	1.43343
76	19850731	PHL501A	8	740.250	22.977	3.92789
77	19860723	BUF501A	13	743.077	113.294	0.82155
78	19850916	ACY501A	4	747.750	68.515	1.42670
79	19850821	ACY501A	5	749.800	61.329	1.62730
80	19860828	BUF501A	15	750.333	76.262	1.31563
81	19860917	BUF501A	11	754.545	113.720	0.91932
82	19840703	ORF501B	4	760.000	41.433	2.65491
83	19800827	SYR501A	4	760.250	62.612	1.76085
84	19860729	BUF501A	10	760.500	102.671	1.07625
85	19850725	PHL501A	8	761.125	56.453	1.96844
86	19860806	BUF501A	15	761.733	95.619	1.16853
87	19000927	PIT501A	7	764.286	72.200	1.58289
88	19860731	PIT501C	8	765.500	89.822	1.28588
89	19850910	ACY501A	4	768.250	42.161	2.80470
90	19850919	ACY501A	8	768.375	70.470	1.67980
91	19860826	BUF501A	4	768.750	62.899	1.88798
92	19860930	BUF501A	10	769.000	105.720	1.12562
93	19860815	PIT501C	8	771.750	71.250	1.70878
94	19850926	ACY501A	8	772.375	79.859	1.53239
95	19850909	ACY501A	8	772.625	83.671	1.46556
96	19850826	ACY501A	9	772.667	69.660	1.76094
97	19850809	ACY501A	7	773.857	55.769	2.22091
98	19860818	PIT501C	8	774.875	89.558	1.39434
99	19001009	PIT501A	8	776.125	53.116	2.37454
100	19001002	PIT501A	7	776.429	63.916	1.97804
101	19850822	ACY501A	9	778.444	99.638	1.28911
102	19850923	ACY501A	7	779.429	50.731	2.55128
103	19860725	PIT501C	8	780.125	91.940	1.41532
104	19850729	PHL501A	8	780.500	50.265	2.59624
105	19840626	ORF501B	4	781.250	63.031	2.08231
106	19860912	ACY501A	8	782.875	41.824	3.17698
107	19840628	ORF501B	4	785.000	54.772	2.46475
108	19860905	BUF501A	23	785.000	85.918	1.57127
109	19850828	ACY501A	10	785.500	104.602	1.29538
110	19860721	BUF501A	13	788.077	141.871	0.97326

TABLE 5.1 (CONTINUED)
MEAN VALUES OF FLEXURAL STRENGTH FOR P-501 CONCRETE
FROM PROJECT TEST SPECIMENS

OBS	TESTDATE	LOT_NO	N_STR	MEAN_STR	STD_STR	Q_STR
111	19850812	ACY501A	6	788.833	57.825	2.4009
112	19860814	BUF501A	4	790.000	197.146	0.7101
113	19000925	PIT501A	6	791.667	156.340	0.9061
114	19850823	ACY501A	8	792.375	70.385	2.0228
115	19860724	PIT501C	8	797.875	99.919	1.4799
116	19860805	PIT501C	8	799.875	58.973	2.5414
117	19840720	ORF501B	4	800.000	61.914	2.4227
118	19850918	ACY501A	9	801.556	36.049	4.2042
119	19860919	BUF501A	6	801.667	92.340	1.6425
120	19850913	ACY501A	9	807.111	79.186	1.9841
121	19840822	ORF501B	4	807.500	99.121	1.5890
122	19860910	BUF501A	17	807.941	96.583	1.6353
123	19860908	BUF501A	25	808.800	122.273	1.2987
124	19850814	ACY501A	8	810.750	84.825	1.8951
125	19860918	BUF501A	17	813.529	81.120	2.0159
126	19850813	ACY501A	7	815.286	37.196	4.4436
127	19840830	ORF501B	4	818.750	64.080	2.6334
128	19860902	PIT501C	6	820.833	82.891	2.0609
129	19860716	BUF501A	8	821.875	157.819	1.0891
130	19860806	PIT501C	7	827.143	106.490	1.6635
131	19860811	PIT501C	4	827.250	78.704	2.2521
132	19860903	PIT501C	8	829.250	44.784	4.0025
133	19840824	ORF501B	4	830.000	14.720	12.2286
134	19860717	PIT501C	4	832.750	78.987	2.3137
135	19860925	BUF501A	13	833.462	109.209	1.6799
136	19850920	ACY501A	9	835.000	82.271	2.2487
137	19850827	ACY501A	10	842.000	106.298	1.8062
138	19861006	PIT501C	6	844.333	10.132	19.1793
139	19860716	PIT501C	6	848.167	75.656	2.6193
140	19860904	PIT501C	6	849.833	87.605	2.2811
141	19850816	ACY501A	7	851.000	53.276	3.7728
142	19850911	ACY501A	8	851.625	81.477	2.4746
143	19860825	PIT501C	7	853.571	72.415	2.8112
144	19831023	ROC501A	4	857.500	68.521	3.1193
145	19860814	PIT501C	8	858.375	31.409	6.6341
146	19850819	ACY501A	4	860.000	38.410	5.4673
147	19850905	ACY501A	8	862.125	37.813	5.6098
148	19860808	PIT501C	8	864.625	87.108	2.4640
149	19860812	PIT501C	7	866.571	40.070	5.4048
150	19860826	PIT501C	8	866.625	66.982	3.2341
151	19860829	PIT501C	8	869.625	70.587	3.1114
152	19860912	BUF501A	4	870.000	63.770	3.4499
153	19800903	SYR501A	4	874.750	58.926	3.8141
154	19831010	ROC501A	4	875.000	47.958	4.6916
155	19850906	ACY501A	8	876.625	50.242	4.5107
156	19851016	SBY501A	4	877.000	41.960	5.4099
157	19840723	ORF501B	4	887.500	46.458	5.1122
158	19860822	PIT501C	7	890.571	74.231	3.2408
159	19870203	ORF501A	4	891.250	24.622	9.7981
160	19831021	ROC501A	4	895.000	54.467	4.4981
161	19850807	ACY501A	5	911.200	42.044	6.2125
162	19831019	ROC501A	5	921.000	37.483	7.2299
163	19851014	SBY501A	7	925.429	49.490	5.5653
164	19870101	ORF501A	4	933.750	4.787	59.2734
165	19851017	SBY501A	4	934.500	37.599	7.5667

TABLE 5.2
VALUES OF QUALITY INDEX, Q, FOR P-501 CONCRETE

OBS	TESTDATE	LOT_NO	N_STR	MEAN_STR	STD_STR	Q_STR
1	19800708	SYR501A	4	667.000	0.000	.
2	19850930	ACY501A	8	552.750	33.225	-2.92693
3	19850924	ACY501A	6	591.167	43.115	-1.36454
4	19851001	ACY501A	10	542.800	149.999	-0.71467
5	19850730	PHL501A	6	600.500	74.675	-0.66289
6	19850722	PHL501A	8	622.875	63.623	-0.42634
7	19860725	IAD501A	6	637.500	49.066	-0.25476
8	19850807	PHL501A	8	637.500	56.609	-0.22081
9	19800802	SYR501A	4	646.500	24.826	-0.14099
10	19860808	BUF501A	16	645.312	35.752	-0.13111
11	19860815	BUF501A	4	648.750	57.355	-0.02179
12	19851002	ACY501A	9	669.111	97.308	0.19640
13	19840706	ORF501B	4	670.000	97.211	0.20574
14	19860627	IAD501A	24	657.917	36.083	0.21940
15	19840714	ORF501B	4	686.250	161.729	0.22414
16	19860607	IAD501A	4	656.250	26.575	0.23519
17	19860819	BUF501A	12	668.750	67.086	0.27949
18	19860722	IAD501A	6	661.667	35.166	0.33176
19	19860731	BUF501A	14	687.500	101.787	0.36842
20	19001008	PIT501A	6	694.500	108.614	0.40971
21	19850802	PHL501A	6	680.333	72.152	0.42041
22	19850723	PHL501A	8	686.250	77.076	0.47031
23	19850815	ACY501A	6	724.500	150.488	0.49505
24	19860725	BUF501A	15	710.133	120.997	0.49698
25	19860625	IAD501A	23	681.304	62.599	0.50007
26	19850925	ACY501A	11	686.818	72.057	0.51096
27	19850801	PHL501A	8	705.375	104.125	0.53181
28	19850815	PHL501A	8	689.375	71.496	0.55073
29	19860804	BUF501A	12	703.750	95.134	0.56499
30	19860626	IAD501A	24	682.292	50.021	0.64556
31	19860605	IAD501A	10	680.500	46.335	0.65825
32	19860814	BUF501A	4	790.000	197.146	0.71013
33	19850719	PHL501A	6	703.500	74.167	0.72135
34	19860606	IAD501A	12	702.083	69.885	0.74527
35	19860902	BUF501A	24	726.458	98.063	0.77969
36	19850806	PHL501A	8	688.375	46.965	0.81710
37	19850717	PHL501A	12	685.167	42.861	0.82048
38	19860723	BUF501A	13	743.077	113.294	0.82155
39	19860904	BUF501A	18	726.389	92.495	0.82587
40	19840711	ORF501B	4	707.500	68.860	0.83503
41	19000925	PIT501A	6	791.667	156.340	0.90614
42	19850809	PHL501A	8	701.625	56.840	0.90824
43	19860623	IAD501A	26	681.038	34.108	0.91005
44	19860825	BUF501A	8	702.500	57.321	0.91589
45	19860917	BUF501A	11	754.545	113.720	0.91932
46	19860718	PIT501C	6	698.500	51.458	0.94252
47	19850718	PHL501A	8	724.250	78.640	0.94418
48	19860721	BUF501A	13	788.077	141.871	0.97326
49	19860905	PIT501C	8	714.500	64.398	1.00158
50	19860820	BUF501A	12	733.333	78.432	1.06250
51	19860729	BUF501A	10	760.500	102.671	1.07625
52	19860716	BUF501A	8	821.875	157.819	1.08907
53	19860812	BUF501A	16	712.187	57.095	1.08918
54	19860930	BUF501A	10	769.000	105.720	1.12562
55	19800430	SYR501A	4	720.000	60.000	1.16667

TABLE 5.2 (CONTINUED)
VALUES OF QUALITY INDEX, Q, FOR P-501 CONCRETE

OBS	TESTDATE	LOT_NO	N_STR	MEAN_STR	STD_STR	Q_STR
55	19860505	BUF501A	15	761.733	95.619	1.16853
57	19840712	ORF501B	4	721.250	56.624	1.25831
58	19800711	SYR501A	4	676.500	21.000	1.26190
59	19860610	IAD501A	28	710.536	47.324	1.27919
60	19860731	PIT501C	8	765.500	89.822	1.28588
61	19850822	ACY501A	9	778.444	99.638	1.28911
62	19850828	ACY501A	10	785.500	104.602	1.29539
63	19860908	BUF501A	25	808.800	122.273	1.29874
64	19850724	PHL501A	8	733.500	64.029	1.30410
65	19860909	BUF501A	5	723.000	55.969	1.30430
66	19800808	SYR501A	4	718.750	52.519	1.30905
67	19860828	BUF501A	15	750.333	76.262	1.31563
68	19800424	SYR501A	4	701.250	37.500	1.36667
69	19860818	PIT501C	8	774.875	89.558	1.39434
70	19860725	PIT501C	8	780.125	91.940	1.41532
71	19850916	ACY501A	4	747.750	68.515	1.42670
72	19800905	SYR501A	4	739.750	62.612	1.43343
73	19850909	ACY501A	8	772.625	83.671	1.46556
74	19860724	PIT501C	8	797.875	99.919	1.47995
75	19850926	ACY501A	8	772.375	79.859	1.53239
76	19860905	BUF501A	23	785.000	85.918	1.57127
77	19000927	PIT501A	7	764.286	72.200	1.58289
78	19800709	SYR501A	4	687.500	23.671	1.58419
79	19840822	ORF501B	4	807.500	99.121	1.58896
80	19850821	ACY501A	5	749.800	61.329	1.62730
81	19860910	BUF501A	17	807.941	96.583	1.63529
82	19850627	PHL501A	6	723.167	44.638	1.63911
83	19860919	BUF501A	6	801.667	92.340	1.64248
84	19860806	PIT501C	7	827.143	106.490	1.66347
85	19850919	ACY501A	8	768.375	70.470	1.67980
86	19860925	BUF501A	13	833.462	109.209	1.67991
87	19860815	PIT501C	8	771.750	71.250	1.70878
88	19800827	SYR501A	4	760.250	62.612	1.76085
89	19850826	ACY501A	9	772.667	69.660	1.76094
90	19860829	BUF501A	8	733.125	46.209	1.79889
91	19850827	ACY501A	10	842.000	106.298	1.80624
92	19800422	SYR501A	4	685.000	19.149	1.82782
93	19860826	BUF501A	4	768.750	62.899	1.88796
94	19850814	ACY501A	8	810.750	84.825	1.89507
95	19850725	PHL501A	8	761.125	56.453	1.96844
96	19001002	PIT501A	7	776.429	63.910	1.97804
97	19850913	ACY501A	9	807.111	79.186	1.98409
98	19860918	BUF501A	17	813.529	81.120	2.01589
99	19850823	ACY501A	8	792.375	70.385	2.02282
100	19860902	PIT501C	6	820.833	82.891	2.06093
101	19840626	ORF501B	4	781.250	63.031	2.08231
102	19850809	ACY501A	7	773.857	55.769	2.22091
103	19850920	ACY501A	9	835.000	82.271	2.24867
104	19860811	PIT501C	4	827.250	78.704	2.25212
105	19800605	SYR501A	4	739.000	39.345	2.26206
106	19860904	PIT501C	6	849.833	87.605	2.28108
107	19860717	PIT501C	4	832.750	78.987	2.31368
108	19860926	BUF501A	6	716.667	28.225	2.36195
109	19001009	PIT501A	8	776.125	53.116	2.37454
110	19850812	ACY501A	6	788.833	57.825	2.40091

TABLE 5.2 (CONTINUED)
VALUES OF QUALITY INDEX, Q, FOR P-501 CONCRETE

OBS	TESTDATE	LOT_NO	N_STR	MEAN_STR	STD_STR	Q_STR
111	19840720	ORF501B	4	800.000	61.9139	2.4227
112	19860809	PIT501C	8	864.625	87.1057	2.4640
113	19840628	ORF501B	4	765.000	54.7723	2.4648
114	19850911	ACY501A	8	851.625	81.4773	2.4746
115	19860805	PIT501C	8	799.875	58.9732	2.5414
116	19850923	ACY501A	7	779.429	50.7308	2.5513
117	19850729	PHL501A	8	780.500	50.2650	2.5962
118	19860716	PIT501C	6	848.167	75.6556	2.6193
119	19840830	ORF501B	4	818.750	64.0800	2.6334
120	19840703	ORF501B	4	760.000	41.4327	2.6549
121	19850910	ACY501A	4	768.250	42.1614	2.8047
122	19860825	PIT501C	7	853.571	72.4151	2.8112
123	19000922	PIT501A	4	737.500	30.8383	2.8374
124	19800502	SYR501A	4	668.750	6.2915	2.9802
125	19840625	ORF501B	4	735.000	27.9881	3.0370
126	19860829	PIT501C	8	869.625	70.5872	3.1114
127	19831028	ROC501A	4	857.500	66.5207	3.1193
128	19860912	ACY501A	8	782.875	41.8242	3.1770
129	19860826	PIT501C	8	866.625	66.9817	3.2341
130	19860822	PIT501C	7	890.571	74.2313	3.2408
131	19800702	SYR501A	4	729.000	24.2487	3.2579
132	19860912	BUF501A	4	870.000	63.7704	3.4499
133	19850816	ACY501A	7	851.000	53.2760	3.7728
134	19800903	SYR501A	4	874.750	58.9258	3.8141
135	19850731	PHL501A	8	740.250	22.9767	3.9279
136	19860903	PIT501C	8	829.250	44.7844	4.0025
137	19850918	ACY501A	9	801.556	36.0490	4.2042
138	19800602	SYR501A	4	739.500	21.0000	4.2619
139	19800703	SYR501A	4	739.500	21.0000	4.2619
140	19850813	ACY501A	7	815.286	37.1964	4.4436
141	19831021	ROC501A	4	895.000	54.4671	4.4981
142	19850906	ACY501A	8	876.625	50.2421	4.5107
143	19831010	ROC501A	4	875.000	47.9583	4.6916
144	19840723	ORF501B	4	887.500	46.4579	5.1122
145	19860812	PIT501C	7	866.571	40.0702	5.4048
146	19851016	SBY501A	4	877.000	41.9603	5.4099
147	19850819	ACY501A	4	860.000	38.4101	5.4673
148	19851014	SBY501A	7	925.429	49.4903	5.5653
149	19850905	ACY501A	8	862.125	37.8132	5.6098
150	19800529	SYR501A	4	710.250	10.5317	5.7208
151	19850807	ACY501A	5	911.200	42.0440	6.2125
152	19860814	PIT501C	8	858.375	31.4095	6.6341
153	19831019	ROC501A	5	921.000	37.4833	7.2299
154	19851017	SBY501A	4	934.500	37.5988	7.5667
155	19870203	ORF501A	4	891.250	24.6221	9.7981
156	19840824	ORF501B	4	830.000	14.7196	12.2286
157	19861006	PIT501C	6	844.333	10.1325	19.1793
158	19870101	ORF501A	4	933.750	4.7871	59.2734

TABLE 5.3
UNIVARIATE ANALYSIS FOR MEAN VALUE OF FLEXURAL STRENGTH
FOR P-501 CONCRETE

UNIVARIATE PROCEDURE

Variable=MEAN_STR

Moments

N	154	Sum Wgts	154
Mean	759.9162	Sum	117027.1
Std Dev	76.70439	Variance	5883.564
Skewness	-0.04201	Kurtosis	-0.19977
USS	89830982	CSS	900185.3
CV	10.0938	Std Mean	6.181016
T:Mean=0	122.9436	Prob>|T|	0.0001
Sgn Rank	5967.5	Prob>|S|	0.0001
Num ^= 0	154		

Quantiles(Def=5)

100% Max	934.5	99%	925.4286
75% Q3	810.75	95%	887.5
50% Med	761.4292	90%	866.5714
25% Q1	703.5	10%	669.1111
0% Min	542.8	5%	645.3125
		1%	552.75
Range	391.7		
Q3-Q1	107.25		
Mode	637.5		

Extremes

Lowest	Obs	Highest	Obs
542.8(	3)	895(	140)
552.75(	1)	911.2(	150)
591.1667(	2)	921(	152)
600.5(	4)	925.4286(	147)
622.875(	5)	934.5(	153)

TABLE 5.4
UNIVARIATE ANALYSIS FOR QUALITY INDEX, (Q), FOR P-501 CONCRETE

UNIVARIATE PROCEDURE

Variable=Q_STR

Moments

N	154	Sum Wgts	154
Mean	1.96244	Sum	302.2158
Std Dev	1.780377	Variance	3.169741
Skewness	1.264815	Kurtosis	2.909319
USS	1078.051	CSS	484.9703
CV	90.72258	Std Mean	0.143467
T:Mean=0	13.67871	Prob>¦T¦	0.0001
Sgn Rank	5685.5	Prob>¦S¦	0.0001
Num ^= 0	154		

Quantiles(Def=5)

100% Max	9.79809	99%	7.566739
75% Q3	2.596239	95%	5.565309
50% Med	1.586579	90%	4.443596
25% Q1	0.83503	10%	0.279491
0% Min	-2.92698	5%	-0.14098
		1%	-1.36454
Range	12.72507		
Q3-Q1	1.761209		
Mode	4.261905		

Extremes

Lowest	Obs	Highest	Obs
-2.92698(	1)	6.212536(	150)
-1.36454(	2)	6.63415(	151)
-0.71467(	3)	7.229881(	152)
-0.66288(	4)	7.566739(	153)
-0.42634(	5)	9.79809(	154)

FREQUENCY OF MEAN_STR

MEAN_STR MIDPOINT		FREQ	CUM FREQ	PERCENT	CUM PERCENT
550	**	2	2	1.30	1.30
575		0	2	0.00	1.30
600	**	2	4	1.30	2.60
625	***	3	7	1.95	4.55
650	******	6	13	3.90	8.44
675	*****************	17	30	11.04	19.48
700	****************	16	46	10.39	29.87
725	*****************	17	63	11.04	40.91
750	***************	15	78	9.74	50.65
775	***********************	23	101	14.94	65.58
800	***************	15	116	9.74	75.32
825	***********	11	127	7.14	82.47
850	**********	10	137	6.49	88.96
875	**********	10	147	6.49	95.45
900	****	4	151	2.60	98.05
925	***	3	154	1.95	100.00
950		0	154	0.00	100.00
975		0	154	0.00	100.00
1000		0	154	0.00	100.00

```
-----+----+----+----+---
     5   10   15   20
```

FREQUENCY

FIGURE 5.1. HISTOGRAM FOR MEAN VALUE OF FLEXURAL STRENGTH FOR P-501 CONCRETE

```
                         FREQUENCY OF Q_STR

Q_STR                                                CUM              CUM
MIDPOINT                                      FREQ   FREQ  PERCENT  PERCENT
         |
  -1.0   |**                                     2      2     1.30     1.30
         |
  -0.5   |****                                   4      6     2.60     3.90
         |
   0.0   |*********                              9     15     5.84     9.74
         |
   0.5   |******************                    18     33    11.69    21.43
         |
   1.0   |**********************                22     55    14.29    35.71
         |
   1.5   |*******************************       31     86    20.13    55.84
         |
   2.0   |****************                      16    102    10.39    66.23
         |
   2.5   |*****************                     17    119    11.04    77.27
         |
   3.0   |**********                            10    129     6.49    83.77
         |
   3.5   |**                                     2    131     1.30    85.06
         |
   4.0   |*****                                  5    136     3.25    88.31
         |
   4.5   |******                                 6    142     3.90    92.21
         |
   5.0   |************                          12    154     7.79   100.00
          -----+----+----+----+----+----+-
               5   10   15   20   25   30

                    FREQUENCY
```

FIGURE 5.2. HISTOGRAM FOR QUALITY INDEX, (Q) FOR P-501 CONCRETE

The histogram for Q, Figure 5.2, is the primary ingredient in the selection of values for AQL and UQL. Figure 5.2 reveals that the 50th percentile has a value of Q between 1.0 and 1.5. If we pick a value for Q within this range, we could use one of the formulas in Chapter 4 to calculate EPAL and this would yield an initial choice for AQL. Unfortunately, the listings in Tables 5.1 through 5.4 are not for consistent sample size.

Recall the restriction on lot size. Lot size was determined in this example for number of test values greater than or equal to four per date and location. As such, the values of Q calculated from these data are based on sample sizes ranging from 4 units to 28 units. Thus, which of the formulas to use from Chapter 4 is unclear in this example.

When the data is arranged so that lot size is (fairly) consistent, calculation of AQL from the appropriate formula of Chapter 4 follows without difficulty. Again, the reason for the choice of value of Q around the 50th percentile is that this value reflects, in the main, what the industry typically produces without undue hardship.

In a similar manner, an initial choice for UQL is made. Again return to the histogram for Q, Figure 5.2. Therein at least 90% of the population is able to produce at a quality level of 0.0 or stated oppositely, only 10% of the population is producing at a value of Q less than 0.0. This can serve as the value of Q from which the value of UQL is calculated. Use one of the formulae in Chapter 4 with the value of Q = 0 and calculate the value for EPAL. This will serve as the initial choice for UQL. A calculation of EPAL to find UQL will not be correct in this example for the reasons cited above. However, this situation notwithstanding, the procedure for calculating QAL and UQL is clear.

It is reminded here that this procedure provides the initial choice for AQL and UQL. It is the responsibility of the agency to determine if these values are indeed reasonable and implementable. To this end, the values of AQL and UQL should be bridged by the procedure outlined in Chapter 4 and the resulting pay factors should be applied to the lots in the data base of question. If the resulting pay factors are either too harsh or too lenient, an iterative procedure should be exercised until the appropriate values for AQL and UQL and pay factors are determined.

For the sake of demonstrating the procedure in detail, ignore the fact that the histogram of Figure 5.11 is not based on lots of same sample size. Suppose it is assumed that the number of samples per lot is 4. Additionally, assume that the 50th percentile for quality index, (Q), is around 1.25 - midway between Q equal to 1.0 and 1.5. Use Equation (4-6), Chapter 4, and calculate $EPAL_4$.

That is:

$$EPAL_4 = 100(1-A) \quad \text{where}$$

$$A = \max[0,\tfrac{1}{2} - \tfrac{1}{2}*Q*(n^{1/2}/n-1)].$$

For $n = 4$ and $Q = 1.25$

$$A = \max\,[0,\ \tfrac{1}{2} - \tfrac{1}{2}*1.25*2/3]$$

$$A = .08333 \quad \text{whereupon}$$

$$EPAL_4 = 91.7 \approx 92$$

Therefore, choose AQL = 91 PAL. In a similar manner, use the value of Q from Figure 5.2 that only 10% of the population are testing below. This turns out to be Q = .2. Again, use Equation (4-6) to calculate EPAL. To this end,

$$A = \max\,[0,\ \tfrac{1}{2} - \tfrac{1}{2}*.2*2/3]$$

$$A = .41 \quad \text{whereupon}$$

$$EPAL_4 = 59.$$

Therefore choose UQL = 59 PAL. These values are (practically) the same as those listed in Chapter 4 and as such, the values for the coefficients required for the quadratic expression that spans the gap between AQL and UQL will be almost the same and so will be the resulting pay factor expression for values of EPAL between EPAL ≈ 90 and EPAL ≈ 60. That is, the expression would turn out to be

$$\text{Pay Factor} = (-3.2120 * EPAL^2) + (6.4847 * EPAL) + (-2.2345)$$

as before. This uses a scaling factor (SF) of 0.6.

6. PAYMENT ADJUSTMENT PLAN (PAP) DISKETTE SYSTEM

6.1 Introduction

This effort is supported on an IBM-compatible floppy data disks in amounts and contents, as required to technically administer a computerized program, default files, and source program listing.

The payment formulas, defaults, payment schedules, acceptance and rejection quality limits, payment factors, and/or other items developed to collect field information are written into an IBM-compatible floppy disk(s) computer program(s) capable of accepting new information and test data to produce payment factor(s).

Hereafter, this software will be referred to as the Payment Adjustment Plan (PAP) diskette system and will consist of several individual computer programs.

This chapter describes the steps used to develop the Payment Adjustment Plan (PAP) diskette system. Throughout the text of this chapter, letters and words within square brackets, [ ], indicate computer keys and/or keyboard keystrokes required to be performed by the computer operator. The square brackets, [ ], are not to be typed as part of the required keystroke input.

6.2 Criteria for Payment Adjustment Plan (PAP) Diskette System

The Payment Adjustment Plan (PAP) diskette system has been developed to provide FAA personnel with a computer program, incorporating payment adjustment schedules/factors, for pavement test results that are below a desirable level. This PAP diskette system may be used by FAA office personnel, FAA field personnel, construction contractors, consultants/engineers, other government agencies, or others as the FAA so elects.

The criteria listed below were developed to produce this PAP diskette system.

Criteria established by definition of the effort are to be as follows:

- o Must be operable on an IBM compatible computer.
- o Must use floppy data disks.
- o Must have contents to technically administer a Payment Adjustment Plan (PAP) computerized program.

- Must contain necessary default files.

- The source program listing must be provided.

Criteria established by the FAA are as follows:

- The program is to be free of proprietary rights.

- The basic keyboard functions are to be similar to the program being written by Engineering Economics Research, Inc. (It was concluded this program was not sufficiently similar to the PAP program to warrant having similar key strokes.)

- To provide FAA office personnel the ability to add/change formula defaults before providing the PAP disk to field personnel.

- To allow field personnel to input new test data and calculate a payment factor based on this new test data.

Additional criteria established by the Contractor to provide a complete, easy to operate, quality program are as follows:

- The floppy disks are to be 5-1/4 inch double-sided, double-density and operable in a computer's Drive A. This size of disk is selected because it is the most common size used on computers. Also, all IBM compatible computers will have a Drive A.

- The program being delivered to field personnel is to be compiled or protected in such a manner as to prohibit field personnel from listing the source code, modifying the program, or changing the FAA input data/formula defaults.

- The PAP programs are to be similar to other programs a computer operator may be familiar with.

- The PAP program is to be "User Friendly", that is, to be operable by field personnel inexperienced in computer operation. Field personnel must have, at least, the ability to boot a computer and load DOS and the PAP program.

- The PAP program is to be "Menu Driven", that is, progress through the program, step-by-step, providing direction to the computer operator as to his next choice or entry.

- The PAP program is to have the [CONTROL-BREAK] key disabled, requiring field personnel to use the Menu Driven program.

- An introduction screen is to provide a basic description of the program. This screen is to include the version date the program was issued.

- One field disk is to contain the following:
  - Airport, Contractor and FAA project information.
  - PAP programs for five specifications.
  - FAA assigned curve defaults.
  - The ability to save data for all included specifications from six projects.
  - Printing ability of data for all specifications and projects.
- The PAP program is to have the ability to input new data, calculate this data into a payment factor based on FAA defaults, and store/file this data and calculations for future recall and FAA use.
- The PAP program is to have the ability to perform quick PAP calculations without saving the test data. This is for "WHAT IF" calculations.
- The PAP program is to contain specific information, such as, the airport, the Contractor, the FAA project, and testing methods.
- The PAP program is to contain specific test information and data, such as, lot numbers, sample locations, test dates, test results and PAP calculations.
- The PAP program is to have the ability to print out (hard copy) test data and PAP calculations.

6.3 Development of the PAP Diskette System

Step One was to develop the P-501 PAP formula into a simple 5-1/4 inch diskette computer program, written in GWBASIC, to input new test data, calculate the sample average, sample standard deviation, estimated Q or QL, estimated PAL and the payment factor. This original program had built in PAL cut-off points and curve slope that resulted in a fixed pay factor formula. Also, this program had the ability to use only four test data entries for each lot for its calculations. No data or calculations of this original program could be saved for future usage.

The built in PAL cut-off points were set as follows:

- Upper PAL = 90 percent (above receives 100 percent payment).

- Lower PAL = 60 percent established at 50 percent payment (below 60 percent PAL received no payment).

- Points between 60 and 90 percent PAL represent a quadratic curve which resulted in payment factor of between 50 to 100 percent payment.

During Step Two, the PAP program was expanded to include an introduction screen, the menu driven ability, six project data files, airport information input, data file saving and printing (hard copy) of data. This expanded program was presented for FAA review.

The FAA requested the four test samples input for each lot be changed to accept from three to six samples for each lot before performing the PAP calculations. This was included as requested.

Step Three was to develop a program that could be used by FAA office personnel to change PAL cut-off default points and the quadratic curve equation and save these default points and equation in a file named "CURVEPAP.FAA." To identify a field disk for a specific airport, the airport and FAA project description information are saved to a file named "CURVINFO.FAA."

The curve calculation program, "FAACURVE.EXE," does not have to be provided on the field PAP disk; however, files "CURVEPAP.FAA" and "CURVEINFO.FAA" are required.

Step Four was to expand the computer PAP diskette system to include several programs and files as follows:

- A quick calculation program.

- A curve modification program.

- A printing (hard copy) program.

- A start (general airport information) program.

- Airport information files.

- Six project files for test data (for each of the five specifications).

- Several FAA default files.

- Several field information files.

During this program expansion, most of the criteria previously established were included successfully.

Step Five was to rewrite these programs into a compiled version of BASIC.

The PAP programs were first rewritten in TurboBasic. A problem of disabling the [CONTROL-BREAK] key was solved; however, the separate programs compiled in .EXE & .TBC files would not "chain" from program to program. Borland International was unable to assist with solving this problem.

The PAP programs were then rewritten in QuickBASIC. The problems of disabling the [CONTROL-BREAK] key and the "chaining" from program to program were solved and overall, the programs functioned satisfactorily.

Other problems that were being encountered were also minimized and will be discussed later.

The problem of insufficient disk space for the operation of the PAP programs was solved by having the pavement test data transferred to a data storage disk in Drive B whenever the field PAP disk in Drive A became full. This process worked successfully; however, (1) Using Drive B was not in the original criteria and (2) The process may be too complex for a novice computer operator to follow.

The disk storage space problem prompted the Contractor to investigate having one PAP diskette for each different material specification. This proved to be a good choice as several separate programs could be condensed into the main program. This was due to the increased operation speed of QuickBASIC over GWBasic. QuickBASIC compiled programs operate on a machine language level, permitting faster operational speed. Combining these programs saved disk space.

Also, using QuickBASIC permitted using "tools" not permitted by GWBasic, such as eliminating line number and using "CALL-SUB" programs. These tools permitted further reducing the disk storage space required.

It was also concluded that providing the field PAP diskette in a compiled QuickBASIC program would solve the problem of computer operators having difficulty in loading the PAP program.

The problem most operators were encountering, using programs written in GWBasic, was that they would load GWBasic from their Drive C and were then unable to load the PAP program from their Drive A. A batch file program was written to solve this problem; however, when this batch file program was tested on several different computers, success was experienced only 85 percent of the time.

As previously mentioned, a program written in compiled QuickBASIC permits an easy and quick way of loading the field PAP program, because it can be loaded directly from the MS-DOS A> prompt, eliminating any need of loading a GWBasic or any other program. The steps required to load the QuickBASIC compiled field PAP program is as follows:

1. The computer must be properly installed with a monitor (preferably a color monitor) and a printer.

2. Start the computer system and boot MS-DOS, as per computer instructions.

3. Insert the FAA Payment Adjustment Plan (PAP) computer program FAA-PAP field disk into the computer's Drive A.

4. Type [A:] and press the [ENTER] key to transfer computer control to the Drive A.

5. From the A> Prompt, load the Payment Adjustment Plan (PAP) data input and pay factor calculation computer program by typing, in capital letters [FAASTART] and pressing the [ENTER] key.

A file name of "FAASTART" was chosen to assist experienced computer operators who will go directly to the computer and do a directory [DIR] of the disk and choose the most likely file to load, which normally will contain a clue in the file name such as "START."

Other criteria areas that deserve an explanation are the "User Friendly" and "Menu Driven" abilities of the PAP programs. These two items are closely associated. A "Menu Driven" program only permits the operator few and logical choices to progress, screen-by-screen, through the program. The [CONTROL-BREAK] key being disabled is vital to a "Menu Driven" program.

A "User Friendly" program is one that communicates, in an understandable language, with the computer operator. This is normally achieved by displaying several tools and statements on each screen, in an easy and understandable language, prompting the operator to take the next step, and even suggesting his next operation, choice or default.

The best and most common example of a "User Friendly" and "Menu Driven" program is the LOTUS 1-2-3 program. A computer operator familiar with programs, such as LOTUS 1-2-3, will not have any difficulty using these PAP programs.

The "User Friendly" and "Menu Driven" tools incorporated in the PAP programs are as follows:

- o Each screen has general characteristics and placements of screen tools to assist the operator during a program session.

- o Each screen of these programs displays 25 horizontal lines (left to right) with each line having up to 80 characters. A character can either be a letter, number or symbol. Vertical (up and down) characters are called columns. Many screens group words or numbers together in columns.

- o The placement of screen tools are as follows:

  Lines 1 and 2: A screen title is displayed to explain the general purpose of the particular information/data required.

  Lines 3 through 20: These lines are the heart of the program and are used for displaying, entering and editing information and data. The required information and data are grouped together in a logical order and each general category of required information has a number to assist the operator to select inputing/editing of information. The computer cursor is located in the active CELL. The active CELL is highlighted in reverse color and the cursor position is indicated by a blinking underline.

  Line 21: This line is not used.

  Lines 22 and 23: During the Response Request Mode, prompts are displayed to instruct the operator for screen approval/ corrections and requests information/data required during program flow.

  Line 24: Indicates current program mode the program is in. The Insert Mode is also highlighted on this line.

  Line 25: Indicates the function keys the program has access to. Not all function keys are active at all times.

- o Modes of Operation:

  Response Request Mode: The Response Request Mode requires an operator response. A selection request is displayed on Lines 22 and 23 of the screen. The operator must respond for the program to continue. Only the keys required to continue are active.

  Input Mode: The Input Mode permits the operator to input information and data into the program and its files. When in the Input Mode, the CELL that is actively receiving the information/data is highlighted in reverse color. The TYPEWRITER

KEYBOARD, [ARROWS], [BACKSPACE], [INSERT], [ESCAPE], [DELETE], and [END] keys are active. The [LEFT and RIGHT ARROW] keys move the cursor left or right within the CELL. The [UP and DOWN ARROW] keys will [ENTER] the information into the CELL and move input/edit to the CELL before or after it, or respond with an [ENTER] and return the program to the Response Request Mode.

Calculation Mode: After necessary data has been entered into the program, the program will calculate the data and return the results and the pavement adjustment payment factor. No input keys are active during the Calculation Mode.

File Processing Mode: The File Processing Mode includes loading of additional program subroutines, transferring programs to other screen inputs, and loading and storing data/information into its files. No input keys are active during the File Processing Mode.

Printing Transfer Mode: The Printing Transfer Mode is used only to transfer information and data from the diskette files to the printer in the printing program.

During developing and testing of the PAP computer program it became apparent, when program errors were encountered, that it was necessary to have a method of communicating between the computer operator and the computer programmer.

A program subroutine was written to analyze error messages. The standard BASIC error number codes were chosen. Common program errors will be handled within the program and the computer operator will not be aware of any problem. Unusual program errors will display a message on Lines 22 and 23, which instructs the computer operator to record the message error and press any key to continue with the program. This message will list an error code number, a line number of the program, and a screen number. If the same error continues, the computer operator should notify FAA personnel with this information, so that, the problem can be resolved. See Table J-1 of Appendix J.

Several persons assisted in testing the "Menu Driven" and "User Friendly" abilities of these programs. Their computer experience ranged from that of an eleven-year-old without any computer experience, to a college graduate with extensive computer science skills. The persons without any knowledge of FAA pavement and test information, required a briefing in this area. These exercises proved quite useful in pointing out shortcomings in the programs and the Operator's Manual that had been developed. Revisions were made to accommodate these shortcomings.

6.4 QuickBASIC Programing

Computer program packages, such as QuickBASIC, have been developed to provide a method for computer programmers to write specialized programs and issue these programs to other computer operators. The FAA field PAP programs are an excellent example of where Quick BASIC compiled programs can be used.

The program writer can program within the QuickBASIC environment, similar to when using GWBasic. After the newly written program is completed and debugged from within the QuickBASIC environment, the QuickBASIC program will compile the new program into an .EXE file that can be run independently of any other program, except MS-DOS.

The compiled .EXE programs require a run module (BRUN45.EXE in this case) that is copyrighted by Microsoft Corporation. However, a registered license of a QuickBASIC program is permitted to generate these compiled .EXE programs and include the run module (BRUN45.EXE) as part of the disk that is provided to other computer operators.

The only disadvantage is that the run module, BRUN45.EXE, uses 77,000 bytes of disk space, which could be used for data storage. For additional details on the Microsoft License Agreement and usage privileges, see Appendix F.

6.5 PAP File Data Transfer to dBASE III

Previous test data collected during Task C were screened and the data that were found to be acceptable were entered into the dBASE III data files for analyzing during Task D, Development of Payment Adjustment Plans. This chapter will not review the methods used in analyzing this data or operation of the dBASE III program.

A study was conducted to make the test data entered into the PAP diskette system files transferable to dBASE III files. A program named "PAPDBASE", was written to accept a PAP data file, evaluate its data, make minor alterations to the storage sequence, and save that PAP data to another file that could be read and loaded by the dBASE III program.

After analyzing that program, it was concluded that by making minor changes in the PAP programs "FAASTART" and "FAAPRINT", PAP test data could be read directly, by a dBASE III program, and stored with the previously collected data in dBASE III files. The data would have to be evaluated using the dBASE III program.

The minor changes required in the PAP programs were: (1) Store data as ASCII characters, (2) Change the data file name extension from .DAT to .TXT, and (3) Add a carriage return and a line feed at the end of each lot. This will result in a data file that can be retrieved by a dBASE III program.

It is recommended that future dBASE III data files follow the dBASE III data "filename" description previously used during Task C data entry. See Appendix G for example. Format should be as follows:

- o The first three or four digits of the "filename" is to be the FAA assigned airport designation, such as for Dulles International Airport being IAD.
- o The next three digits is to be the FAA assigned number of the specification, such as for P-501, Portland Cement Concrete Pavement being 501.
- o The last digit is to be a sequential designation, using alphabetical letters A through Z.

Therefore, the third project on file for P-501 at Washington Dulles International Airport would have a "filename" of "IAD501C".

The following will explain one method for transferring PAP data to a dBASE III file. The directions are for use with a computer having both A and B drives. The "filename" will refer to the newly established file name of a dBASE III file described above.

Step 1: Insert the field PAP data diskette returned from the field with the newly added data into Drive A. Insert a newly formatted disk into Drive B.

Step 2: From the DOS A> prompt, perform a [COPY A:*.TXT B:] and press the [Enter] key.

Step 3: Leaving the disk in Drive B, replace the disk in Drive A with the office PAP disk.

Step 4: From the DOS A> prompt, perform a [COPY A:MASTER.DBF B:filename.DBF] and press the [Enter] key.

Step 5: Repeat Step 4 for each of the files to be transferred to dBASE III.

Step 6: Insert the dBASE III system disks into Drive A and load the dBASE III operating program into the computer.

Step 7: From the ASSIST screen/menu, position the highlight to the Setup/Database file and press the [Enter] key. This will display drive choices.

Step 8: Position the highlight to Drive B and press the [Enter] key. This will display the name of the files currently on the selected drive.

Step 9: Position the highlight to the "filename" you wish to work with and press the [Enter] key.

Step 10: This will display the question "Is the file indexed? [Y/N]". Respond with pressing the [N] key and the [Enter] key. This will transfer dBASE III program control to the selected file.

Note the drive and the "filename" appears on the highlighted line at the bottom of the screen, as the second and third entry, respectively.

Step 11: Press the escape [ESC] key, transferring the program control to the command line, which is the fourth line from the bottom of the screen.

Step 12: From the command line, type [APPEND FROM PAP-AA.TXT SDF] and press the [Enter] key. In lieu of the file PAP-AA.TXT, you may use the name of another file as required.

This program will display the number of records that were transferred into the dBASE III files.

Step 13: From the command line, type [ASSIST] and press the [Enter] key. This will transfer program control back to the ASSIST screen/menu.

At this point, the data transferred to the dBASE III files can be viewed and edited by positioning the highlight to the Update/ Browse position and pressing the [Enter] key. To view data to the right of the screen, hold down the control [CTRL] key and press the [right arrow] key.

Or, transfer additional files from the PAP files to the dBASE III files, repeat Steps 7 through 13.

Step 14: Exit dBASE III from the ASSIST screen/menu by positioning the highlight to Set Up/Quit dBASE III and pressing the [Enter] key. This will transfer computer control to MS-DOS.

Step 15: Leaving the disk in Drive B, insert the proper Task C dBASE data disk in Drive A, perform a directory [DIR/W A:] to verify there is not any duplication of file names with the newly created files, otherwise, the older files will be destroyed.

Step 16: Type [COPY B:*.DBF A:] and press [Enter] key.

This concludes one method of transferring PAP field collected data into the dBASE III data base files.

Usage and analysis of this dBASE III data is described in another chapter.

6.6 Payment Adjustment Plan (PAP) Computer Program

The Payment Adjustment Plan (PAP) diskette system was designed to provide acceptance/rejection and payment adjustment schedules for Federal Aviation Administration (FAA) airport pavement projects.

The PAP diskette system computer programs developed will function on an IBM compatible computer with MS-DOS (Disk Operating System) (Microsoft) using a 5-1/4" double-sided, double-density floppy disk. For optimum screen response, a color monitor should be used.

The PAP diskette system is to be used in Drive A of the computer hardware. Using other drives is the responsibility of the user.

There are three main PAP computer programs that make up the PAP diskette system. These programs are as follows:

FAASTART.BAS/.EXE	For field personnel use. This program contains all project information and test data input, PAP formulas, calculation of the PAP, and saving input and calculations for future recall and FAA use. This program uses the PAP defaults that were established by FAA office personnel using the FAACURVE program.
FAAPRINT.BAS/.EXE	For producing a printout (hardcopy) of the project information, pavement test data, and the PAP calculations.
FAACURVE.BAS/.EXE	For use by FAA office personnel only, to change PAP defaults. This program is not required for field personnel.

Information files that are required for successful operation of the PAP programs are as follows:

CURVINFO.FAA	Airport information to identify the disk with input by FAA office personnel.
CURVEPAP.FAA	PAP formula defaults established by FAA office personnel.
INFO-GEN.FAA	Airport information with input by field personnel.
INFO-PAP.FAA	PAP testing information with input by field personnel.

DRIVE.MAP — The computer program uses this file to keep track of the project files.

Test data files that are generated by the computer program to save the test data for five projects are as follows:

PAP-AA.TXT
PAP-BB.TXT
PAP-CC.TXT
PAP-DD.TXT
PAP-EE.TXT

A run module required for operation of the PAP diskette system is as follows:

BRUN45.EXE — This file/program is a run module that is required for proper operation of the FAA-CURVE, FAASTART and FAAPRINT programs. This program is copyrighted by Microsoft Corporation and requires a statement to this effect on each disk and program introduction screen that is provided to field personnel.

These aforementioned files constitute the PAP computer diskette system. All files/programs, except FAACURVE, are required for the successful operation of the field PAP computer programs.

The field PAP computer programs can be loaded into a properly installed IBM compatible computer by: (1) Inserting the Field PAP diskette into the computer's Drive A, (2) Typing [A:] and pressing the [ENTER] key, and (3) Typing [FAASTART] and pressing the [ENTER] key.

The PAP computer programs are Menu Driven and the program flow proceeds from screen to screen throughout the program. There is one menu screen to permit selecting airport information input, printer and exiting to MS-DOS. The program flow diagram is shown in Figure 1 of the Operator's Manual, Volume II, of this report.

The program flow is as follows:

Introduction Screen: The Introduction Screen provides a brief description of the project and includes the version date of the program. Press the [Y] or [ENTER] key to continue.

General Information Screen: The General Information Screen is for Airport, Consultant, Contractor, and Test Laboratory information input.

Pavement and Project Screen: The Pavement and Project Screen requests a specific pavement material specification and a specific project name (location) within the overall construction contract to enable the PAP program to group data into their proper category and file.

A project is defined as work being performed that must be grouped together to allow for a proper pay adjustment. The airport design consultant or engineer should indicate what constitutes a project and a project name. One contractor can be constructing several projects at once throughout the same airport. Caution must be taken to keep and enter the test laboratory results in the proper project.

Data and Information Screens: After the material specifications and project name are properly selected, the PAP program continues to the testing information screen which permits entering the Methods of Testing and the required target specification, such as for P-501 (Flex Strength), 700 psi.

After entering the Target Specifications and Methods of Testing Screen, the program continues permitting entering lot numbers, exact test location, sample/test dates and the Laboratory test results. The program will then calculate the acceptance and the pay adjustment of the entered tests.

The PAP program will save the entered airport information, testing information, pavement test date, and the pay adjustment in the program diskette files.

Menu Screen: At several points in the PAP program, selecting the [F2] function key will display the Main Menu. The Main Menu permits returning to previously displayed screens, selecting HELP screens, selecting printing of a hardcopy, selecting a QUICK CHECK screen, and exiting to MS-DOS.

Help Screen: At several points in the PAP program, selecting the [F1] function key will display several HELP screens as follows:

HELP Screen 1, Program Flow.
HELP Screen 2, Key Description.
HELP Screen 3, Function Keys.

Printer Screen: Used to select files and to produce a printed hardcopy of data in the computer files. A sample of the P-501 Concrete test data printout is included herein as Appendix G.

QUICK CHECK Screen: The QUICK CHECK screen will permit an easy and quick method to input pavement test data and calculate the payment adjustment factors. This input data or the calculated payment adjustment factors will not be saved, nor can it be sent to a printer.

EXIT: EXIT will cancel the program and return the computer command to MS-DOS.

6.7 PAP Computer Program Operator's Manual

An operator's manual was written to assist persons in understanding the programs and the required inputs. Experienced computer operators may not need to refer to the manual as the PAP programs are "User Friendly" and "Menu Driven." Operators familiar with Lotus 1-2-3 will find keystrokes similar and will not have any difficulty using this program.

The PAP Computer Program Operator's Manual is published as Volume II of this report.

6.8 FAA Office Procedures

There are two levels of FAA office procedures which are as follows:

- o Generating a disk containing the field PAP computer programs from a master PAP computer program disk that contains .EXE files. Appendix J, Curve Default Program, is an Operator's Manual for this program.

- o Changing/modifying the source code of the programs and compiling these changes/modifications into a master PAP computer program disk.

The source code programs will have an extension of .BAS and the compiled master PAP computer programs will have an extension of .EXE.

The first procedure generating a field PAP disk has simple and easy steps.

A master PAP computer program disk must exist containing the following files:

FAASTART.EXE
FAAPRINT.EXE
FAACURVE.EXE
BRUN45.EXE
CURVINFO.FAA
CURVEPAP.FAA
INFO-GEN.FAA
INFO-PAP.FAA

The computer operator should do a directory [DIR] to verify these files are available on the master disk.

All files should not have any information or data stored in them except the CURVEPAP.FAA file.

To generate the field PAP computer disk, proceed as follows:

- o Insert the aforementioned master PAP computer disk into Drive A and a blank formatted disk in Drive B of an IBM compatible computer.

- o From the DOS level prompt, type [A:] and press the [ENTER] key.

- o From the A> prompt, type [DISKCOPY A: B:] and press the [ENTER] key.

- o Follow instructions from your computer.

- o Remove the master PAP computer disk from Drive A and return to storage.

- o Remove the field PAP computer disk from Drive B and insert in Drive A.

- o With the field PAP computer disk in Drive A and from the A> prompt on the screen, type [FAASTART] and press the [ENTER] key.

- o The program FAASTART will load into the computer's memory.

- o From the Introduction Screen, type [CURVE] and the program FAACURVE will automatically load into the computer's memory.

- o The FAA office computer operator can move from screen-to-screen making desired changes to the PAP defaults and airport information.

- o After all desired changes are made, the FAA office computer operator must save [S] these defaults to the proper CURVINFO.FAA and CURVEPAP.FAA files. The save process has been designed to be an easy process for the operator. After evoking the save process, the computer will do most of the work.

- o After properly saving the defaults, the operator can choose to return to the MS-DOS level or reload the FAASTART program.

- o From the MS-DOS level A> prompt, type [DEL FAACURVE.EXE] and press the [ENTER] key. This step removes the curve default program FAACURVE from the field PAP disk. If deleting this program is neglected, field personnel will still be unable to load this program into the computer's memory without knowing the password. If the FAA office personnel wants to modify the defaults after deleting the FAACURVE program, a [COPY FAACURVE.EXE A: B:] of the file FAACURVE.EXE from the master disk, it is recommended that the file be removed from the disk, since this allows more disk storage space for data.

- o Label the field PAP disk with the following information:
  - Field PAP Calculation Program.
  - For (airport and city/state).
  - Date: (Use date field program was made).
  - Portions (c) 1982-1988 Microsoft Corporation. All Rights Reserved.
  - Enter FAASTART to run program.
- o If a record/backup of the field PAP disk issued is desired, generate a [DISKCOPY] as described above. Label the record/backup copy and store.

The above listed steps do not require FAA office personnel to work within the QuickBASIC environment; however, a field PAP computer program disk can be made from within the QuickBASIC environment.

The other procedure, changing/modifying the source code, requires a knowledge of programming in a BASIC language and familiarity of the QuickBASIC programming tools. The FAA computer program source code is written in a BASIC language, has a file extension of .BAS, saved in a ASCII format, and can best be changed/modified within the QuickBASIC environment.

The advantages of programming within a QuickBASIC environment and utilizing the many QuickBASIC tools are too numerous to list within this report. These advantages and tools can be studied in the texts: "Microsoft QuickBASIC Programming in BASIC" and "Microsoft QuickBASIC Learning to Use Microsoft QuickBASIC."

Programs written within the QuickBASIC environment uses all the commands available in BASIC, plus additional commands that simplify and improve programming. When the program is completed, run and debugged, the QuickBASIC environment will generate a compiled .EXE program from the source code .BAS program. This compiled .EXE program can then be run without requiring any other program, except MS-DOS.

Programming within the QuickBASIC environment can be done on a computer without a fixed Drive C; however, because the QuickBASIC program package contains five disks, programming speed is increased if the computer Drive C is used.

6.9 Recommendations

The advantages of providing the field PAP diskette system in QuickBASIC compiled programs are as follows:

- Simplicity of loading the FAA field PAP computer programs.
- A QuickBASIC compiled program is more compatible with an "IBM compatible computer," than a program written in Basic, Basica, or GWBasic.
- The [CONTROL-BREAK] key is disabled permitting "Menu Driven" programs.
- A field based computer operator cannot make a listing of the source code of the programs or change/modify the program.
- Another program, such as Basic, Basica, or GWBasic, is not required for the PAP programs to operate. The work normally performed by a BASIC program will be done by the run modules BRUN45.EXE, which is included on the field disk.
- Line numbers are not required when writing programs in QuickBASIC. This saves disk space and time.
- The calculation and processing speed is greatly increased over a GWBasic written program; because compiled programs operate on a machine language level.
- There are many programming tools QuickBASIC has that are not available in GWBasic. These tools are detailed in the QuickBASIC manuals.

The disadvantages of programming in a QuickBASIC compiled program are as follows:

- The run module, BRUN45.EXE, uses 77,000 bytes of disk space, which could be used for data storage.
- A statement "Portions (C) 1982-1988 MICROSOFT Corporation. All rights reserved" must appear on (1) the disk label and (2) the program's first introduction screen. This is to be in accordance with the license agreement of MICROSOFT Corporation.

Comparing the advantages and disadvantages of programming in a QuickBASIC compiled program, it is the Contractor's recommendation that the FAA field PAP programs be provided to field personnel in a compiled QuickBASIC version.

7. RANK AND SELECT THREE AIRPORT PAVEMENT PROJECTS

7.1 General

The study required testing of the pavement adjustment system developed during Task F with pavement test data from three airports having applicable new pavement construction. This chapter explains the process used for the selection of the three airports.

7.2 Development of Airport Pavement Construction Project Criteria

Criteria were established to assist in the selection of the best applicable airport projects for testing the payment adjustment system during Task F. The criteria used for selecting the airport construction projects are as follows:

- The airport should be located in the FAA Eastern Region.
- Airports should have as many of the required five specifications as possible.
- The construction project should comply with the latest FAA specification.
- Each project must have at least 20 test points.
- The contractor must be a "Competent Contractor".
- Density tests must be performed by the sand-cone method.
- P-501 Concrete to be tested by the flexural strength beam testing method.

7.3 Selection of Three Airport Construction Projects

Meetings with airport managers, consultants, and engineers during the Task C, Data Collection phase, did not generate a positive list of airports that were having applicable pavement construction for the 1988 and 1989 seasons. Consequently, a list of airports having construction projects was generated from FAA records. Investigation of these airports revealed that few were having pavement type construction of the required specifications. Further pursuit of applicable data from the airports noted on this list was discontinued.

A meeting with personnel of the FAA Eastern Region's Falls Church District office indicated very little airport construction was being performed during the 1988 and 1989 seasons on the applicable specifications except P-152, Excavation and Embankment. The parties agreed to provide pavement test data from the Dulles International Airport, Washington D.C., as the data become available. Expected data were for P-152, P-209, and P-501.

Meetings were conducted with other airport managers and consultants that were anticipating pavement construction, with only one consultant positively having applicable airport construction during the 1988 and 1989 season. This consultant was R. Kenneth Weeks, Engineers, of Norfolk, VA. The project was for a Terminal Apron expansion at the Norfolk International Airport, Norfolk, VA, using P-501 Concrete pavement.

Personnel from the Greater Pittsburgh International Airport, Pittsburgh, PA were contacted for possible projects. The airport personnel referred the Contractor to the airports Construction Manager, Mellon Stuart Company, Dick Enterprises. The Mellon Stuart Company, Dick Enterprises indicated there was a Midfield Terminal project at the Greater Pittsburgh International Airport, Pittsburgh, PA being constructed and they would provide pavement test data for Items P-152, Excavation and Embankment and P-501, Portland Cement Concrete Pavement.

The Greiner Engineering Services, Inc., Baltimore, MD provided P-501, Portland Cement Concrete Pavement test data for the Baltimore/Washington International Airport, Baltimore, MD for a Pier D/Y Headstand project. The test data were received too late to be used by the Contractor during Task F, Analyzing of Collected Data.

A meeting was held with representatives of the National Ready Mixed Concrete Association and the American Concrete Pavement Association. They indicated that they did not have P-501 Concrete test data from the FAA Eastern Region. However, they did have, and offered to provide, P-501 Concrete test data from the Wichita Mid-Continent Airport, Wichita, Kansas for review and use.

As a result of Task C, Data Collection interviews between the Contractors' personnel and FAA field personnel, airport personnel, and consulting engineers, it was apparent that most engineering monitors preferred a construction contractor to continue to rework compactible type material until a "pass" was obtained from the "pass/fail" tests, rather than offer a payment adjustment for the section for which the tests failed. This situation was consistent with that discovered by the FAA Operation personnel in interviews with pavement industry personnel and field engineers.

Pavement materials currently under density testing consideration are as follows:

P-152, Excavation and Embankment, Density.
P-209, Crushed Aggregate Base Course, Density.
P-304, Concrete Treated Base Course, Density.
P-306, Econocrete Subbase Course, Density.

The Contractor did not review and has not made recommendations for any other density testing materials beyond the four aforementioned materials.

The Contractor was unable to locate any airport pavement projects in the FAA Eastern Region being constructed using P-306, Econocrete Subbase Course, for the 1988 and 1989 seasons.

Based on the above listed recommendations, the only material specification to require testing of the developed methodology, formulation and diskette system was P-501, Portland Cement Concrete Pavement (flexural strength). Of the above listed five airports, the three that received the highest rating for the previously established criteria were as follows:

1. Greater Pittsburgh International Airport, Pittsburgh, PA.
2. Norfolk International Airport, Norfolk, VA.
3. Dulles International Airport, Washington D.C.

The FAA approved using these three airports as the P-501 Concrete projects for field testing of the newly developed PAP system.

8. FIELD EVALUATION OF AIRPORT PAVEMENT CONSTRUCTION PROJECTS

8.1 General

To verify the payment adjustment (PAP) system developed, the PAP system was tested with three airport pavement construction projects. This chapter explains the airport pavement construction projects used for this process.

As indicated in Chapter 2, the only material specification that was to be monitored during Task F was P-501, Portland Cement Concrete Pavement.

During the development of the payment adjustment methodology, system analysis of data and development of the PAP formulation, Task D, frequent panel discussions were held concerning quality control. The objective of payment adjustment quality control is to encourage maintaining and improving on a good quality of materials, and if below an acceptable quality limit (AQL), to offer an adjusted payment, dependent on lower quality, until an Unacceptable Quality (UQL) is reached. It is at this Unacceptable Quality (UQL) point that the material is rejected.

8.2 Airport Pavement Construction Test Data Used for Verification

The three airport pavement projects listed in Chapter 7, Greater Pittsburgh, Norfolk, and Dulles, were the primary projects that were considered; however, two additional airport pavement projects (Baltimore/Washington and Wichita Mid-Continent) were also reviewed.

The original P-501 Concrete flexural strength test data (approximately 50 Lots) received for Norfolk International Airport was used by the computer programmer during the development of the PAP computer program system, Task D. The remainder of the Norfolk test data and the other four projects were used at various times to verify and debug the PAP computer program system.

Details of the P-501 Concrete test data received and the payment adjustment results are as follows:

1. Greater Pittsburgh International Airport, Pittsburgh, PA

   The pavement test data were provided by the Mellon Stuart Company, Dick Enterprises and are of a Midfield Terminal project constructed in 1989. The material specification was for P-501, Portland Cement Concrete Pavement (flexural strength).

Flexural strength tests were conducted by Mellon Stuart Company, Dick Enterprises. Their record keeping and test result data sheets were excellent.

Sufficient testing of the concrete was performed each day to facilitate grouping tests into lots of 28-day tests. This resulted in 113 lots.

The design target was established at 750 PSI for the flexural strength beam tests. Basing the PAP formula defaults of AQL equal to 90 percent, UQL equal to 60 percent and a scaling factor of 0.6, the payment schedule results for each lot are shown in Appendix J.

Analysis of these results is as follows:

- o Data entry personnel did not experience any problems with the information/data entry ability of the computer program.
- o All data for the 113 lots of the P-501 Concrete for the Pittsburgh project were analyzed with the computer program, and provided satisfactory results without difficulty. Pay factors produced were within expected projections.

2. Norfolk International Airport, Norfolk, Virginia

The pavement test data were provided by R. Kenneth Weeks, Engineers of Norfolk, Virginia and are of a Terminal Apron Expansion, constructed in late 1987 and 1988. The material specification was for P-501, Portland Cement Concrete Pavement (flexural strength).

Flexural strength tests were conducted by ATEC Associates of Virginia, Inc. of Norfolk, Virginia. Their record keeping and data sheets were very good. As they had required only two passing beam tests for each lot, the data was entered into the PAP computer programs in two arrangements and under different project files. The first entry was by lots, as originally designated, using both 14-day and 28-day tests. It should be noted, some lots (17, 18, 19, 20, and 31) had only 14-day tests performed on the flexural strength beams. This resulted in 99 lots and is shown in Appendix K. The second entry combined reasonable tests on the same day, to form new lots of 28-days only. This resulted in 44 lots and is shown in Appendix L.

The design target was established at 700 PSI for flexural strength beam tests. Basing the PAP formula defaults of AQL equal to 90 percent, UQL equal to 60 percent, and a scaling factor of 0.6, the payment schedule results for each lot are shown in Appendix K and L.

Analysis of these results is follows:

- The first series of test data received were used to assist the computer programmer during the writing of the program. The remainder permitted the computer programmer to verify and debug the program. This provided vital hands-on experience for the computer programmer to evaluate and incorporate typical test data and information that are expected to be available during pavement construction. As would be expected during the debugging of any new computer program, considerable problems were encountered; however, all problems were isolated and the program was corrected, so as to avoid similar problems in the future.

- The later data entry of the 28-day tests only resulted in few problems with the computer program.

- During the transfer of the data from the PAP files to dBase III files, there was a problem encountered with the lots that followed those lots that did not have any data assigned to them. The problem was isolated and corrected.

- All data for the 44 (28-day) lots of the P-501 Concrete for the Norfolk project were analyzed with the computer program and provided satisfactory results without difficulty. Pay factors produced were within expected projections.

3. Dulles International Airport, Washington D.C.

Pavement test data were provided by the FAA Falls Church District of Falls Church, Virginia and are for a Runway No. 30 Concrete Pavement at Dulles International Airport. This construction was between June 1988 and October 1988. The material specification was for P-501, Portland Cement Concrete Pavement (flexural strength).

Flexural strength tests were conducted by ATEC Associates of Virginia, Inc. of Chantilly, Virginia.

As they had required only two passing tests at either 14 days or 28 days, most were accepted at 14-days; therefore, data would enter into the PAP computer program in two arrangements in different files. The first entry was by lots, as originally designated, using the latest four tests of 7-day, 14-day, or 28-day tests. This resulted in 51 lots and is shown in Appendix M. The second data entry was by combining reasonable tests on the same day into new lots of the best four tests from two lots. This resulted in 25 lots and is shown in Appendix N.

The design target was established as 650 PSI for the flexural strength beam tests by the airport design engineers. Basing the PAP formula defaults as AQL equal to 90 percent, UQL equal to 60 percent, and a scaling factor of 0.6, the payment schedule results for each lot are shown in Appendices M and N.

Analysis of these results is as follows:

- o Few data entry problems were encountered as the program was already debugged. Any problems encountered were isolated and corrected.

- o A problem was encountered while transferring data from the PAP data files to the dBase III files. This problem could not be solved, so the data were reentered into the PAP program under another project file. The data base was correctly transferred from the PAP data files into the dBase III files.

- o All data for the 25 lots of the P-501 Concrete for the Dulles project were analyzed with the computer program, and provided satisfactory results without difficulty. Pay factors produced were within expected projections.

The above three airport projects were selected for testing of the payment adjustment system. P-501 Concrete test data from two additional airport projects were available and were tested. Results are as follows:

4. Baltimore/Washington International, Baltimore, Maryland

Pavement test data were provided by the Greiner Engineering Services, Inc. of Baltimore, Maryland and were for a Pier D/Y Headstand concrete pavement. This construction occurred between August and November of 1987. The material specification was for P-501, Portland Cement Concrete Pavement (flexural strength).

Flexural strength tests were conducted by Penniman and Browne, Inc. of Baltimore, Maryland. Their data sheets are a combination of flexural strength test results and core thickness test results.

Most lots had at least three flexural strength tests. In the cases when only one or two were performed, the tests were combined with an adjacent day's lots and entered into the PAP computer files. This was for Lots 1, 11 and 17. This resulted in the data entry of 20 lots and is shown in Appendix O.

The design target was established at 700 PSI for flexural strength beam tests. By using the PAP formula defaults of AQL equal to 90 percent, UQL equal to 60 percent, and a scaling factor of 0.6, the payment schedule results for each lot are shown in Appendix O.

Analysis of these results is as follows:

- o There were no major problems encountered during the data entry with the FAA computer program, or when transferring this data to the dBase III files.

- o All data for the 20 lots of the P-501 Concrete for the Baltimore/Washington International project were analyzed with the computer program and provided satisfactory results without difficulty. Pay factors produced were within expected projections.

5. Wichita Mid-Continent Airport, Wichita, Kansas

The pavement test data were provided by the National Ready Mixed Concrete Association/National Aggregates Association of Silver Spring, Maryland, and are for a Runway 1L-19R reconstruction concrete pavement project. This construction was between July and October 1987. The material specification was for P-501, Portland Cement Concrete Pavement (flexutal strength).

Flexural strength tests were conducted by Professional Engineering Consultants, Wichita, Kansas. During pavement construction, a comparison test was conducted between flexural strength, compressive strength, and splitting tensile strength tests. 28-day flexural strength tests were performed in groups, either four or eight tests per lot. For entering this data into the PAP computer program, the lots having eight tests were divided into two lots of four consecutive tests each. This resulted in 65 lots.

The design target was established by the airport design engineer at 650 PSI for the flexural strength beam tests. Basing the PAP formula defaults on AQL equal to 90 percent, UQL equal to 60 percent, and a scaling factor of 0.6, the payment schedule results for each lot are shown in Appendix P.

This project is included for informational purposes. It cannot be reviewed in conjunction with the data from the FAA Eastern Region, as the projects utilized in this study must all be from the same FAA region.

Analysis of these results is as follows:

- There was no major problems encountered during the data entry with the FAA computer program, or when transferring this data to the dBase III files.

- All data for the 65 lots of the P-501 Concrete for the Wichita Mid-Continent project were analyzed with the computer program, and provided satisfactory results without difficulty. Pay factors produced were within expected projections.

9. RESULTS OF APPLYING PAYMENT ADJUSTMENT PLAN TO AIRPORT CONSTRUCTION PROJECTS

9.1 Preliminary Remarks

As discussed in Chapter 8, data from airport construction projects were used to verify the payment adjustment plan that was developed during Task D. The rationale for choice of values for AQL and UQL was also previously discussed in Chapter 5, and emphasis was placed on the fact that those values were based on historical data for the construction items of interest, which in this effort was P-501 Concrete flexural strength. The historical data were obtained from airport projects that dated from 1974 through 1986. What will be discussed in this chapter are the results that occurred from applying the PAP to recent airport construction projects, that included P-501 Concrete as one of the construction materials.

9.2 Application of the PAP to Recent Airport Construction Projects

9.2.1 Greater Pittsburgh International Airport

Data from this project for P-501 Concrete flexural strength involved the time period from August through December 1989. As pointed out in Chapter 8, these data resulted in one hundred thirteen (113) lots that were subjected to the PAP. The PAP was based on AQL, UQL, scale factor (SF), and minimum pay values of 90%, 60%, 0.60, and 50%, respectively. This means that all values of EPAL $\geq$ 90% received full pay; values of EPAL = 60% received 50% of full pay; all values of EPAL <60% received zero pay; and all values of EPAL for which 60% < EPAL < 90% received an adjusted pay according to the form

$$\text{PAY FACTOR} = -3.21*\text{EPAL}^2 + 6.48*\text{EPAL} - 2.234$$

This is the same expression that was developed in Chapter 4 and justified in Chapter 5.

The values of adjusted pay for the 113 lots are listed in Appendix J. From that listing, 60 lots received full pay; 21 lots received between 99% and 90% of full pay; 13 lots received between 89% and 80% of full pay; 5 lots received between 79% and 70% of full pay; 8 lots received between 69% and 50% of full pay, and 6 lots received zero pay, the minimum.

If these data are subjected to the pay factor that is currently in use by FAA for P-501 Concrete (see Chapter 4), an entirely different and much more lenient pay factor results. All lots except those whose EPAL is less than 60% would receive full pay. This translates to 107 lots receiving full pay, 3 lots receiving between 99% and 90% of full pay and 3 lots receiving between 89% and 80% of full pay. The reason for this is obvious from Figure 9.1, wherein the graphical representation of pay factor versus EPAL is shown. Both curves in Figure 9.1 were taken from Chapter 4. In Figure 9.1, the curve representing the pay factor that resulted from the current work provides for zero pay at the same point (EPAL = 60%), wherein the pay factor from the currently FAA used adjustment curve begins to decrease from full pay.

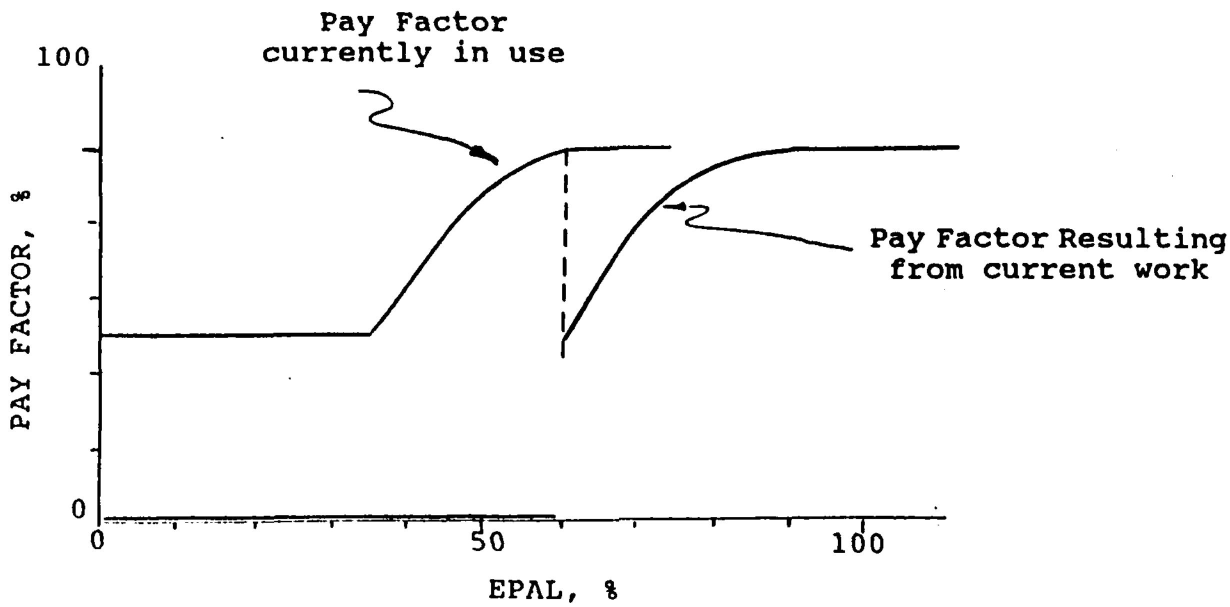


FIGURE 9.1 EPAL VS. PAY FACTOR

An interesting facet associated with the pay factor that resulted from this current work is the influence that the standard deviation (S) has on the pay factor for a particular lot. Look at the listing in Appendix D and specifically at the results for lots 5 and 6. Recall that the lower specification limit for flexural strength for this project was 750 psi. Lot 5 has an average value for stress = 763 psi, an EPAL = .82 and a pay factor of about 92%. Lot 6 has an average value for stress = 760, only 3 psi different from the value of stress for lot 5. However, the pay factor for lot 6 is zero (since EPAL = .56 which is <.60, the limiting value for pay factor different from zero).

The difference between pay factors for lots 5 and 6 lies in the difference in standard deviation for the two lots. Note for lot 5, S = 13.3, while for lot 6, S = 54.7. Standard deviation is a good measure of the spread or variation from the mean value that the values from the sample possess. Note from the members of the sample from lot 5, that the maximum difference between individual values for stress and the average sample value is 23 psi. The sample values for stress in lot 5 are tightly nested about the mean value. Just the opposite is true for the values of stress from the samples for lot 6. Thus, S is a good measure of test result variability and plays a strong role in estimating the impact of this variability on the pay factor. Large variability in quality should be penalized and the formulation from this work provides for that aspect. A cursory look through the remaining elements in the listing of Appendix J supports this finding.

9.2.2 Norfolk International Airport

Data for this project for P-501 Concrete flexural strength involved the time period from November 1987 to October 1988. As noted previously, an arrangement of this data provided for forty-five lots to be subjected to the pay adjustment scheme (see Chapter 8). For consistency with the previous work, the PAP was based on AQL = 90%, UQL = 60%, SF = .60, and pay (at EPAL = 60%) = 50%.

This is the same as before, that is,

Pay factor = 1.00 for EPAL $\geq$ 90%
Pay factor = 0.50 for EPAL = 60%
Pay factor = 0 for EPAL < 60%
and Pay factor (for 60% <EPAL < 90%) is calculated according to

$$\text{PAY FACTOR} = -3.21*\text{EPAL}^2 + 6.48*\text{EPAL} - 2.234$$

The values for pay factor for the 45 lots from the Norfolk project are listed in Appendix L. Therein all lots except four received full pay. Three of those four lots received pay factors between 90% to 95% of full pay and the remaining lot received 89% of full pay. The reason for the lack of significant reductions in pay factor is due to the fact that the lower specification value for flexural stress was 700 psi for this project (compared to a specification value of 750 psi for the Pittsburgh project). This, and also the sample average stress values were not only appreciably above the specification value of 700 psi, but generally the standard deviation values were not large compared to the level of lot average value of stress.

9.2.3 Dulles International Airport

Data for the Dulles project were received and manipulated, as discussed in Chapter 8, to provide data for 25 lots. These data were obtained from tests conducted during the July to September 1988 timeframe. Again, the same values for AQL, UQL, SF, and minimum pay were used in the model for pay factors as used for estimating pay factors for the Pittsburgh and Norfolk projects.

The values for pay factor for the 25 lots (as arranged per the discussion in Chapter 8) for the Dulles project are listed in Appendix N. From the listing in Appendix N, all lots received full pay. Simply stated, all average values for flexural stress for the 25 lots were well above the lower specification value of 650 psi. In fact, there were no values of flexural stress from the individual sample values less than the 650 psi lower limit. Thus, it would be difficult to generate a pay factor less than one unless a large variation in stress values occurred within a lot which is measured by the standard deviation.

Also, as mentioned in Chapter 8, data were made available from two additional airport projects, Wichita and Baltimore/Washington. As such, these two projects were subjected to the pay adjustment model and, therefore, these results will also be discussed.

9.2.4 Baltimore/Washington International Airport

Data for this project resulted from tests conducted during the August to November 1987 time period. The data were arranged per the discussion in Chapter 8 and resulted in 20 lots for analysis. The same values for AQL, UQL, SF and minimum pay as used before were used in the estimation for pay factor for this project. The values for pay factor are listed in Appendix O.

Therein, 18 of 20 lots received full pay and the remaining two lots received pay factors of 98% and 88% of full pay. The 88% of full pay (lot 15) value was due to the relatively large value (95 psi) of standard deviation relative to the average value (783 psi) of flexural stress for this lot.

9.2.5 Wichita Mid-Continent Airport

Although this data can not be judged/reviewed in reality, according to data from the FAA Eastern Region, nonetheless it was subjected to the pay factor model. Data were available for the time period covering July 1987 through October 1987. Sixty-five (65) lots resulted from the flexural strength tests conducted during this time period and are listed in Appendix P.

The same parametric values were used to estimate pay factors for the 65 lots of this project, as were used in the previous projects. That is, AQL = 90%, UQL = 60%, SF = .60 and minimum pay (@EPAL = 60%) = 50%.

The results of subjecting the data from this project to the pay adjustment factor model are also listed in Appendix P. Therein, 55 lots received full pay; 2 lots received between 99% and 90% of full pay; 3 lots received between 89% and 80% of full pay; 1 lot received 73% of full pay; 1 lot received 57% of full pay; and 3 lots received no pay. The lower specification value for flexural stress for this project was 650 psi.

In Subsection 9.2.1, reference was made to the fact that the pay factor that results from the work of this program is more stringent than that currently in use by the FAA. However, it must be kept in mind that the central point of this project is to determine if the method generally employed in determining pay factors for P-401 Asphalt is applicable to other airport construction materials. That point has definitely been proven to be true. Additionally, a rational approach was needed for choice of the parametric values in the pay factor model.

The approach taken in this project was based on actual data taken from the field for the particular construction item of interest. As such, the resulting pay adjustment model reflects in reality what industry is able to achieve, quality wise, without undue hardship or expense. Therefore, if the resulting pay factor model appears to be more stringent than that currently in use by the FAA, then this difference should be couched in the context of an attempt to improve the overall quality of the end item product (P-501 Concrete), but under the conditions that this is what the industry is able to achieve in a reasonable manner.

In order to bring this issue into perspective, the results from applying the pay factor model to the five projects discussed in this chapter have been lumped together and are listed in Table 9.1.

TABLE 9.1
DISTRIBUTION OF PAY FACTORS FOR FIVE AIRPORT PROJECTS

	Pay Factor, %						
Project	100	99-90	89-80	79-70	69-50	0	TOTAL
Pitt	60	21	13	5	8	6	113
Norfolk	41	3	1	-	-	-	45
Dulles	25	-	-	-	-	-	25
BWI	18	1	1	-	-	-	20
Wichita	55	2	3	1	1	3	65
TOTALS	199	27	18	6	9	9	268

Therein, altogether 268 lots were examined by the pay factor model and 199 of these lots (or 74% of the total number of lots for these five projects) received 100% of full pay. Twenty-seven lots received between 99% and 90% of full pay; eighteen lots received between 89% and 80% of full pay; six lots received between 79% and 70% of full pay; nine lots received between 69% and 50% of full pay and only nine lots received no pay. This says that over 93% of all the lots received at least 70% of full pay, and only about 3%

received no pay. It should also be noted here that these values could be improved to a better level, by a tighter control over product variability, herein measured by standard deviation.

As was seen in an earlier discussion, reduction in the standard deviation for the samples in a lot can have a dramatic effect on estimated quality and, subsequently, on estimated pay factor. But this is precisely the point regarding an attempt at product quality improvement. Reduce product variability and improve product quality. Reduction in standard deviation per sample is the key to quality improvement and is the statistical monitor of quality for this model.

10. ADAPTATION OF PAYMENT ADJUSTMENT PLAN TO OTHER MATERIALS

10.1 Application of Methodology to Other Materials in General

In Chapter 4, (Subsections 4.3.3 through 4.3.7) the applicability of the methodology to other material specifications P-152, Excavation and Embankment, Density; P-209, Crushed Aggregate Base Course, Density; P-304, Cement Treated Base Course, Density; P-306, Econocrete Subbase Course, Density; and P-501, Portland Cement Concrete Pavement, Thickness was discussed. For the reasons stated therein, the applicability of the methodology to these specific construction items was deemed inappropriate. However, since the current FAA specification for P-306 Econocrete involves pay adjustment based on thickness with limitations placed on slump, air content and compressive strength and since compressive strength for P-306 Econocrete is monitored in almost the same manner as that for P-501 Concrete flexural strength, a pay factor for P-306 Econocrete, based on compressive strength, could be accomplished. What follows in the next subsections are the results of applying the methodology to this item.

10.2 Application of Methodology to P-306 Econocrete Compressive Strength

Data for P-306, Econocrete Subbase Course (compressive strength) were received from two project sites, Pittsburgh International Airport and Harrisburg International Airport. The time period for which test data were taken spanned from July 1986 through September 1986 for the Pittsburgh Airport and from November 1983 up to May 1986 for the Harrisburg Airport. The data were screened for admissible lots under the restrictions that the reported values for compressive strength were from 28-day cure batches and a minimum of 3 samples per lot. This screening criteria resulted in 19 admissible lots from the Pittsburgh Airport and 26 admissible lots from the Harrisburg Airport for a total of 45 lots. These lots are listed in Table 10.1.

TABLE 10.1
DETERMINATION OF AQL AND UQL USING P-306 DATA
Performed on lots of 28-day strength
Lots with >= 3 samples

OBS	TESTDATE	LOT_NO	N_STR	MEAN_STR	STD_STR	Q_STR
1	19860509	MDT306A	3	753.33	11.547	0.2887
2	19860408	MDT306A	6	881.67	73.052	1.8024
3	19860410	MDT306A	6	888.33	24.014	5.7606
4	19860401	MDT306A	3	893.33	23.094	6.2065
5	19860728	PIT306A	4	946.25	114.150	1.7192
6	19860730	PIT306A	4	968.00	192.227	1.1341
7	19860402	MDT306A	3	976.67	11.547	19.6299
8	19860729	PIT306A	4	977.00	39.387	5.7633
9	19860409	MDT306A	6	993.33	150.953	1.6120
10	19860425	MDT306A	3	1010.00	20.000	13.0000
11	19860328	MDT306A	3	1026.67	35.119	7.8780
12	19860331	MDT306A	3	1026.67	15.275	18.1121
13	19860827	PIT306A	4	1039.00	72.778	3.9710
14	19860912	PIT306A	4	1078.75	114.596	2.8688
15	19860725	PIT306A	4	1083.50	199.321	1.6732
16	19860415	MDT306A	3	1085.00	8.660	38.6825
17	19860421	MDT306A	6	1088.33	359.968	0.9399
18	19860404	MDT306D	4	1092.25	169.683	2.0170
19	19860828	PIT306A	3	1126.00	87.069	4.3184
20	19860807	PIT306A	4	1154.00	120.036	3.3657
21	19860411	MDT306A	3	1163.33	11.547	35.7957
22	19860403	MDT306A	3	1170.00	20.000	21.0000
23	19860804	PIT306A	4	1171.50	181.118	2.3272
24	19860407	MDT306A	6	1173.33	237.795	1.7802
25	19860911	PIT306A	4	1180.25	46.421	9.2684
26	19860404	MDT306A	6	1186.67	79.162	5.5161
27	19860910	PIT306A	4	1246.75	41.939	11.8445
28	19860714	PIT306A	4	1255.75	72.016	7.0228
29	19860908	PIT306A	4	1291.00	38.114	14.1943
30	19831122	MDT306C	4	1300.50	490.745	1.1218
31	19860326	MDT306A	3	1320.00	36.056	15.8090
32	19860424	MDT306A	3	1326.67	15.275	37.7517
33	19860718	PIT306A	4	1339.50	201.875	2.9201
34	19860701	PIT306A	4	1410.50	199.862	3.3048
35	19851211	MDT306D	4	1419.50	128.648	5.2041
36	19851210	MDT306D	4	1432.75	51.745	13.1944
37	19831116	MDT306C	4	1458.75	89.712	7.9003
38	19860707	PIT306A	4	1490.00	106.464	6.9507
39	19860723	PIT306A	4	1494.50	144.975	5.1354
40	19860702	PIT306A	4	1498.50	311.279	2.4046
41	19831115	MDT306C	4	1733.00	128.898	7.6262
42	19831118	MDT306C	4	1741.75	116.903	8.4835
43	19860719	PIT306A	4	1750.50	442.180	2.2627
44	19831121	MDT306C	4	1777.50	139.115	7.3860
45	19831117	MDT306C	4	2020.25	22.187	57.2527

10.2.1 PAP When Only the Lower Limit for Compressive Strength is Specified

The lower target value for compressive strength for P-306 Econocrete was 750 psi for each of the 45 lots. There was no upper limit (apparently) specified for the compressive strength for these lots. From the listing in Table 10.1, there is only one value for compressive strength that would possibly not receive full pay, if only the lower limit of 750 psi is required for acceptance of this material item. That value is from the Harrisburg International Airport and the test date was May 9, 1986 for three samples whose average value for compressive strength was 753.3 psi, with a standard deviation of 14 and Quality Index Q = .289.

Further calculations show EPAL = 58% for this lot. Use of the technique outlined in Chapter 5 for choice of AQL and UQL emphasizes the ability of the remaining 44 lots from these two projects to each receive almost full pay.

However, this technique must be applied within all the elements of the specification for the material item. These items include the fact that average value of 28-day compressive strength neads to be at least 750 psi, and no more than 20% of the specimens tested have a strength value less than 750 psi. Thus, if the suggested method for choices of AQL and UQL, as outlined in Chapter 5, are followed blindly, the 50th percentile choice for AQL (based on a mean value of compressive strength = 117 psi, the 50th percentile) would result in Q = 5.7 (see Table 10.2), which corresponds to a EPAL = 100%. On the other hand, the 10th percentile choice for UQL (based on the 10th percentile mean value of compressive strength = 946.25 psi) would result in Q = 1.6 (see Table 10.2), which also corresponds to an EPAL = 100%. If taken literally, this would say that all values of compressive strength, whose average value is less than 946 psi and corresponding Q is less than 1.6, may receive a significant adjustment in pay. This, of course, is incorrect because when the items of the specifications are considered (average lot compressive strength = 750 psi and no more than 20% of the samples are less than 750 psi for the lot), practically all lots except the one mentioned above should receive close to full pay. As such, a choice of UQL may not be able to be based on only the project data available and on mechanical use of the technique of Chapter 5. Further scrutiny of the data is required, until additional (project) data are available to supplement that on hand for choice of UQL.

TABLE 10.2

DETERMINATION OF AQL AND UQL USING P-306 DATA
Performed on lots of 28-day strength
Lots with >= 3 samples

UNIVARIATE PROCEDURE

Variable=Q_STR

Moments

N	45	Sum Wgts	45
Mean	9.648894	Sum	434.2002
Std Dev	11.84554	Variance	140.3168
Skewness	2.391665	Kurtosis	6.095318
USS	10363.49	CSS	6173.939
CV	122.7658	Std Mean	1.765829
T:Mean=0	5.46423	Prob>|T|	0.0001
Sgn Rank	517.5	Prob>|S|	0.0001
Num ^= 0	45		

Quantiles(Def=5)

100% Max	57.25275	99%	57.25275
75% Q3	11.84446	95%	37.7517
50% Med	5.760556	90%	21
25% Q1	2.327214	10%	1.611986
0% Min	0.288675	5%	1.121765
		1%	0.288675
Range	56.96407		
Q3-Q1	9.517245		
Mode	0.288675		

Extremes

Lowest	Obs	Highest	Obs
0.288675(	1)	21(	22)
0.939899(	17)	35.79572(	21)
1.121765(	30)	37.7517(	32)
1.134074(	6)	38.68247(	16)
1.611986(	9)	57.25275(	45)

An alternative for choice of UQL may consist of a guess of value for UQL that would seem to be reasonable and consistent with the data that are available. As an example, consider a choice of UQL = 70 EPAL and suppose this corresponds for lots of sample size of 4. The formulas of Chapter 4 can provide the means to aid in judgement for the choice of UQL. That is

$EPAL_4$ = [1-A]*100 and here $EPAL_4$ was chosen = 70. That is,

70 = 100*[1-A] which implies A = .3

Further use of the formulas from Chapter 4 allows

$A = \text{Max. } [0;\ 1/2 - 1/2*Q*(n^{1/2}/n-1)]$ or

$.3 = 1/2 - 1/2*Q*2/3$ for $0<A$. Whereupon

$Q = 0.6$

That is, if Q $\geq$ 6, this corresponds to a UQL = 70 EPAL, which probably suits the P-306 Econocrete compressive strength data fairly well since all lots, except the lot from May 9, 1986, would receive almost full pay. Only the lot where Q = .289 (see Table 10.1) would receive zero pay, while lots for Observations 2, 3, and 4 would receive slightly less than full pay.

The results of the foregoing analysis are illustrated in Figure 10.1. Therein, AQL = 100%, UQL = 70%, the SF = 0.60, and the pay factor is determined from the equation when 70% < EPAL < 100

$$\text{PAY FACTOR} = -3.212*EPAL^2+7.127*EPAL-2.915$$

and

$$\begin{aligned} \text{PAY FACTOR} &= 1.00 \text{ for EPAL} \geq 100 \\ &= 0.50 \text{ for EPAL} = 70 \\ &= 0 \quad\ \text{ for EPAL} < 70 \end{aligned}$$

According to this model, Observation 1 would receive zero pay; Observation 2 would receive 77% of full pay; Observation 3 would receive 91% of full pay; Observation 4 would receive 95% of full pay; and all other observations would receive full pay.

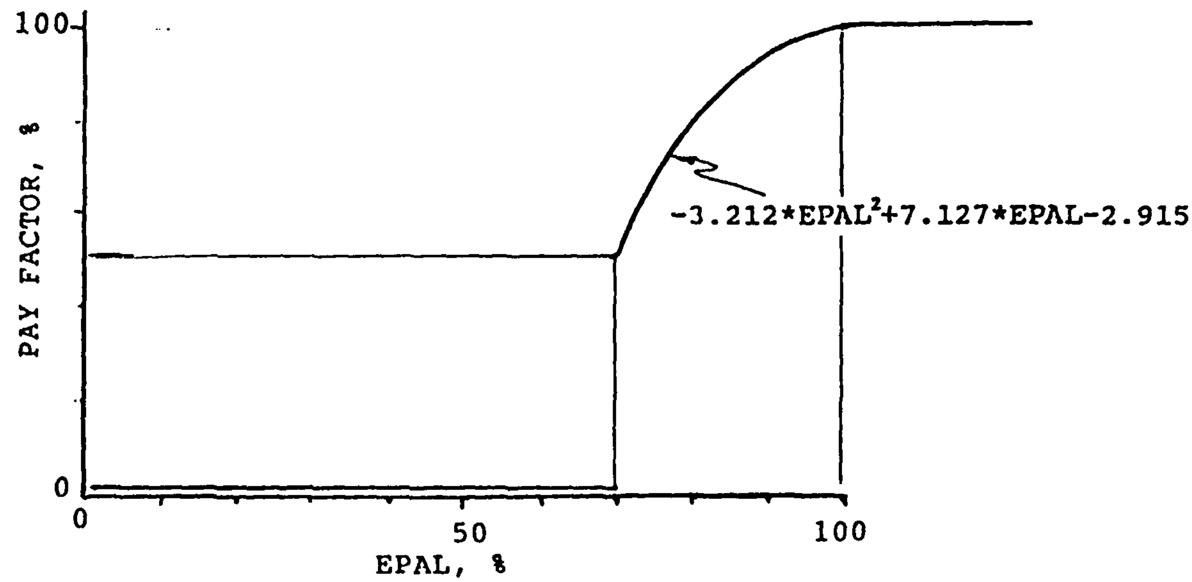


FIGURE 10.1 PAY FACTOR VERSUS EPAL

10.2.2 PAP When Lower and Upper Limits for Compressive Strength are Specified.

In the previous paragraphs, the discussion centered on the PAP when only a lower limit for compressive strength was specified under the constraints of average lot compressive strength and percentage of lot members allowed below the lower strength value. There should also be consideration for the situation when both upper and lower limits for compressive strength are specified for the material item, in this case P-306, Econocrete. In fact, one of the elements within the specifications for acceptance of P-306 Econocrete, based on compressive strength, is that the engineer may specify an upper limit of 1200 psi. What follows is a discussion that addresses the issue when both upper and lower limits are specified for the material item.

In most of the previous discussion, the reference has been made to percent above limit (PAL or EPAL) which was appropriate for the case when only a lower value was specified for the material item. However, when lower and upper limits are specified, reference should be made to percent within limit (PWL or EPWL), since for acceptance the value of the attribute (compressive strength) must on the average (and within the remaining requirements of the elements specified for acceptance) be at least equal to the lower limit. Additionally, the average value must not exceed the upper limit; that is, lower limit ≤ compressive strength ≤ upper limit. Thus, this attribute actually must satisfy the requirement of a

PWL. In order to accommodate the PWL (or EPWL), the following considerations were included in the PAP.

The data from the Pittsburgh and Harrisburg airports were analyzed and subjected to the same requirements (average 28-day strength ≥ 750 psi) as before, with the added requirement that in the main, the lot compressive strength must not exceed 1200 psi. The results of doing this are presented in Table 10.3, wherein the last column represents the probability that the lot would lie between the 750 psi and 1200 psi limits. Thus, increasing values of EPWL are shown in the last column of Table 10.3 and it is clear that out of the 45 candidate lots for acceptance, only 33 lots have values of EPWL >0. The univariate analyses for the probability (EPWL) is shown in Table 10.4, wherein the 50th percentile has an EPWL = 55.6% and a 10th percentile EPWL = 0%. Thus, if these two values are selected for AQL and UQL, an expression for the pay factor can be written using the quadratic expression from Chapter 4 for 0 ≤ EPWL ≤ 55 as

$$\text{PAY FACTOR} = -1.911*\text{EPWL}^2+2.869*\text{EPWL}$$

For EPWL > 55, PAY FACTOR = 1.0

The pay factor versus EPWL is graphically illustrated in Figure 10.2.

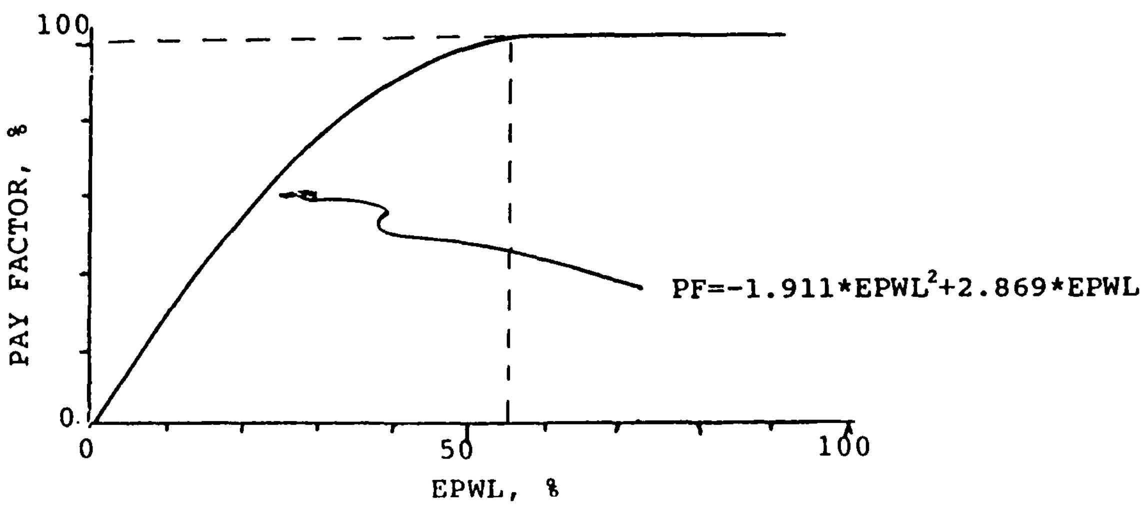


FIGURE 10.2 PAY FACTOR VERSUS EPWL

In all likelihood, the reference data for compressive strength from the Pittsburgh and Harrisburg projects were not subjected to the upper limit value and, as such, the curve of Figure 10.2 is biased significantly to the left. In other words, if future data is collected for P-306 Econocrete compressive strength, under the restrictions of lower <u>and</u> upper strength limits, the curve will shift to the right, which will be more in line with the functional form between Pay Factor and P-501 Concrete flexural strength.

TABLE 10.3
DETERMINATION OF AQL AND UQL USING P-306 DATA
Performed on lots of 28-day strength
Lots with >= 3 samples

OBS	TESTDATE	LOT_NO	N_STR	MEAN_STR	STD_STR	P1	P2	PROB
1	19831117	MDT306C	4	2020.25	22.187	0.00000	1.00000	0.00000
2	19860424	MDT306A	3	1326.67	15.275	0.00000	1.00000	0.00000
3	19831118	MDT306C	4	1741.75	116.903	0.00000	1.00000	0.00000
4	19851210	MDT306D	4	1432.75	51.745	0.00000	1.00000	0.00000
5	19831121	MDT306C	4	1777.50	139.115	0.00000	1.00000	0.00000
6	19831115	MDT306C	4	1733.00	128.898	0.00000	1.00000	0.00000
7	19860326	MDT306A	3	1320.00	36.056	0.00000	1.00000	0.00000
8	19831116	MDT306C	4	1458.75	89.712	0.00000	1.00000	0.00000
9	19860707	PIT306A	4	1490.00	106.464	0.00000	1.00000	0.00000
10	19860908	PIT306A	4	1291.00	38.114	0.00000	1.00000	0.00000
11	19860723	PIT306A	4	1494.50	144.975	0.00000	1.00000	0.00000
12	19851211	MDT306D	4	1419.50	128.648	0.00000	1.00000	0.00000
13	19860719	PIT306A	4	1750.50	442.180	0.00000	0.91499	0.08501
14	19860910	PIT306A	4	1246.75	41.939	0.00000	0.87157	0.12843
15	19860701	PIT306A	4	1410.50	199.862	0.00000	0.85107	0.14893
16	19860702	PIT306A	4	1498.50	311.279	0.00000	0.81965	0.18035
17	19860714	PIT306A	4	1255.75	72.016	0.00000	0.75805	0.24195
18	19860718	PIT306A	4	1339.50	201.875	0.00000	0.73034	0.26966
19	19831122	MDT306C	4	1300.50	490.745	0.12608	0.56826	0.30566
20	19860421	MDT306A	6	1088.33	359.968	0.18670	0.39660	0.41670
21	19860407	MDT306A	6	1173.33	237.795	0.00000	0.46262	0.53738
22	19860804	PIT306A	4	1171.50	181.118	0.00000	0.44755	0.55245
23	19860404	MDT306A	6	1186.67	79.162	0.00000	0.44386	0.55614
24	19860509	MDT306A	3	753.33	11.547	0.40377	0.00000	0.59623
25	19860807	PIT306A	4	1154.00	120.036	0.00000	0.37226	0.62774
26	19860911	PIT306A	4	1180.25	46.421	0.00000	0.35818	0.64182
27	19860725	PIT306A	4	1083.50	199.321	0.00000	0.30517	0.69483
28	19860404	MDT306D	4	1092.25	169.683	0.00000	0.28833	0.71167
29	19860730	PIT306A	4	968.00	192.227	0.12198	0.09770	0.78033
30	19860828	PIT306A	3	1126.00	87.069	0.00000	0.21670	0.78330
31	19860912	PIT306A	4	1078.75	114.596	0.00000	0.14731	0.85269
32	19860409	MDT306A	6	993.33	150.953	0.00000	0.04364	0.95636
33	19860328	MDT306A	3	1026.67	35.119	0.00000	0.00000	1.00000
34	19860331	MDT306A	3	1026.67	15.275	0.00000	0.00000	1.00000
35	19860401	MDT306A	3	893.33	23.094	0.00000	0.00000	1.00000
36	19860402	MDT306A	3	976.67	11.547	0.00000	0.00000	1.00000
37	19860403	MDT306A	3	1170.00	20.000	0.00000	0.00000	1.00000
38	19860408	MDT306A	6	881.67	73.052	0.00000	0.00000	1.00000
39	19860410	MDT306A	6	888.33	24.014	0.00000	0.00000	1.00000
40	19860411	MDT306A	3	1163.33	11.547	0.00000	0.00000	1.00000
41	19860415	MDT306A	3	1085.00	8.660	0.00000	0.00000	1.00000
42	19860425	MDT306A	3	1010.00	20.000	0.00000	0.00000	1.00000
43	19860728	PIT306A	4	946.25	114.150	0.00000	0.00000	1.00000
44	19860729	PIT306A	4	977.00	39.387	0.00000	0.00000	1.00000
45	19860827	PIT306A	4	1039.00	72.778	0.00000	0.00000	1.00000

TABLE 10.4

DETERMINATION OF AQL AND UQL USING P-306 DATA

Performed on lots of 28-day strength

Lots with >= 3 samples

UNIVARIATE PROCEDURE

Variable=PROB

Moments

<table>
<tr><td>N</td><td>45</td><td>Sum Wgts</td><td>45</td></tr>
<tr><td>Mean</td><td>0.512614</td><td>Sum</td><td>23.06763</td></tr>
<tr><td>Std Dev</td><td>0.414788</td><td>Variance</td><td>0.172049</td></tr>
<tr><td>Skewness</td><td>-0.0636</td><td>Kurtosis</td><td>-1.69908</td></tr>
<tr><td>USS</td><td>19.39493</td><td>CSS</td><td>7.570147</td></tr>
<tr><td>CV</td><td>80.91619</td><td>Std Mean</td><td>0.061833</td></tr>
<tr><td>T:Mean=0</td><td>8.290311</td><td>Prob>|T|</td><td>0.0001</td></tr>
<tr><td>Sgn Rank</td><td>280.5</td><td>Prob>|S|</td><td>0.0001</td></tr>
<tr><td>Num ^= 0</td><td>33</td><td></td><td></td></tr>
</table>

Quantiles(Def=5)

100% Max	1	99%	1
75% Q3	1	95%	1
50% Med	0.556143	90%	1
25% Q1	0	10%	0
0% Min	0	5%	0
		1%	0
Range	1		
Q3-Q1	1		
Mode	1		

Extremes

Lowest	Obs	Highest	Obs
0(	12)	1(	41)
0(	11)	1(	42)
0(	10)	1(	43)
0(	9)	1(	44)
0(	8)	1(	45)

11.0 QUALITY CONTROL SPECIFICATIONS FOR P-501, CONCRETE

11.1 Background

One of the main factors for implementation of the technology from this project lies in the impact of this work on the specifications for airport construction material items of interest. Since the focus of this work rests primarily with P-501 Concrete flexural strength for the reasons stated in Subsections 4.3.3 through 4.3.7 and later in Section 10.1, the following discussion pertains solely to the impact of this work on the specification for P-501 Concrete flexural strength. Reference is made to a Draft Specification for P-501 Concrete that was issued for review by the Federal Aviation Administration. Specifically, the discussion that follows is primarily concerned with Paragraph 501-4.21, Acceptance Sampling and Testing, from that Draft Specification for P-501 Concrete.

11.2 Comments Pertaining to the Federal Aviation Administration Draft Specification for P-501 Concrete

There may be some concern over the method outlined in the specification, that is suggested to determine lot quality, because of the manner in which sample values for lots are determined. In Paragraph 501-4.21b., Pavement Strength, the following is quoted:

> "Each lot (a lot is defined as one day's production) shall be divided into four equal sublots. One sample shall be taken, for each sublot, from the plastic concrete delivered to the job site. [For flexural strength determination, two specimens shall be made from each sample and the average of the two shall be the strength for that sublot.] Random sampling locations shall be determined by the Engineer in accordance with procedures contained in ASTM-D3665."

The question has been raised for the case of determining strength of the lot by using the average value for each sublot. It has been suggested that all eight values of strength (2 values per sublot and 4 sublots), taken together, be used to determine the average value of strength for the lot. The resulting quality estimate for the lot would be based on the average value of strength for the lot and the standard deviation of lot, when all values from the sublots are used individually in the calculation of the standard deviation. If this is done, it would tend to mask the impact of sublot importance on estimation of quality for the lot. If, in fact, the purpose of the sublot is to capture the influence of production throughout the day, this aspect is clouded when all values are taken together. On the other hand, if the average value for two specimens is used per sublot, then the influence of each sublot will be present in the estimation for lot quality, and variability throughout the production day can be monitored. Additionally, because of the very nature of testing (for flexural strength) there is always the possibility that one of the specimens in the sublot would not be admissible for testing, due to damage or improper care during the 28-day cure period. If this happens, then the surviving specimen can be tested and the resulting value used to represent the strength of the subject. In the event that both specimens are rendered not useable for testing, then the number of sublots that make up the lot is reduced by one, but this does not destroy the influence of variability from sublot to sublot for the lot.

Having said the foregoing, it would seem that the method that is suggested for estimating pavement strength per Paragraph 501.21b. is completely in order and should remain as is.

A second concern is involved with the expression that is used to estimate unit price, in the event that the lot strength value or PWL is below 85%. The expression quoted in Paragraph 501-4.21d. for this purpose is:

$$PAP = -5.3333 * PWL + 9.7334 * PWL - 3.4200$$

It may be a better choice to leave the expression in the more general form:

$$PAP = A * PWL + B * PWL + C$$

where A, B, and C are values that shall be specified by the Federal Aviation Administration Regional Office, or on a per project basis, whichever is most appropriate. In this way, proper reflection of the past history for the attribute can be incorporated into the formulation by the procedures outlined in Chapters 4 and 5. Also, the percentage of 85% should not be "hard wired" in the specification for minimum PWL for which pay factor is full price. Instead, AQL should be specified as the value at and above which values of PWL receive full pay and below which an adjustment in price paid is made. The value of AQL should also be determined by the Federal Aviation Administration Regional Office, or on a per project basis, using historical information (data base) and the methods outlined in Chapters 4 and 5.

12. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

12.1 Summary

The objective of this study was to develop a statistically based acceptance plan and a payment adjustment schedule applicable for five specification items. These are:

P-152, Excavation and Embankment.
P-209, Crushed Aggregate Base Course.
P-304, Cement Treated Base Course.
P-306, Econocrete Subbase Course.
P-501, Portland Cement Concrete Pavement.

The study was divided into three work elements.

- o Work Element No. 1 included literature review and collection of historical construction data.
- o Work Element No. 2 included statistical analysis of the collected data and development of the pay adjustment plan.
- o Work Element No. 3 included field verification, at three airport construction sites, of plans developed in Work Element No. 2.

Quality Control between a supplier and a consumer is normally an acceptance/rejection of the product(s) being supplied. This means that a product(s) found to be below an acceptable quality limit (AQL) will be returned to the supplier. This is similar to what is currently being used for P-152, Excavation and Embankment, density; such as, when a test fails a specified limit, the work is rejected and the contractor reworks the area until the tests indicate a pass.

A variation of this acceptance/rejection quality control would be to have full payment above the acceptable quality limit, (AQL) a reject (zero payment) below a lower unacceptable quality limit (UAL) and a curved or straight line between these two points, indicating a progressive payment adjustment. This is currently similar to the P-401 Asphalt Concrete payment adjustment schedule.

The methodology of this quality control was the focus of Work Element No. 2, which consisted of reviewing current acceptable methodologies, statistically analyzing test data from previously constructed pavements, developing a Payment Adjustment Plan using this methodology, and statistically analyzing the data and incorporating this Payment Adjustment Plan into a computerized program.

In Work Element No. 3, the methodology and formulation that had been developed and implemented into the computer program during Work Element No. 2, was verified using data from recent airport construction projects for Item P-501, Portland Cement Concrete Pavement (flexural strength). Application of the method provides for a payment factor for the material item, that is consistent and fair, and is based on past pavement construction test data.

Additionally, the methodology and formulation system was extended to Item P-306, Econocrete (compressive strength), being based on the limited amount of available pavement construction test data for this use.

12.2 Conclusions

Based upon the results obtained in Work Element No. 2, the following conclusions can be drawn:

The technology that was used in the specification for P-401 Asphalt Concrete has been successfully expanded and improved upon to establish statistically based acceptance and pay adjustment plans for P-501 Concrete flexural strength. Application of this methodology to the five specifications listed in Section 6.1 for density is not practical or deemed implementable. However, use of the technology for P-306 Econocrete compressive strength, appears to be worthwhile.

The general consensus of persons interested in the quality control of density testing of pavements is that it can best be maintained by accept/ reject quality control (also known as pass/fail). These include P-152, Excavation and Embankment; P-209, Crushed Aggregate Base Course; and P-304, Cement Treated Base Course.

It has also been discovered that most engineers designing concrete pavements prefer to have thickness testing performed on the forms prior to pouring concrete, in lieu of core testing for thickness. These include P-306, Econocrete and P-501, Portland Cement Concrete Pavement.

12.3 Recommendations

During the data collection and entry tasks of this study, it was discovered that much test data was poorly documented, even to the point that some test data sheets did not identify what type material the tests were for, or for what airport or project they applied to. Also, many failed tests did not indicate retests. An example of highly organized and easily usable test records have been developed by The Construction Testing Division of ASW Environmental Consultants, Inc., Allentown, PA.

Recommendations are as follows:

- It is recommended that the FAA develop and utilize a standard format for field and laboratory pavement test data sheets for all FAA pavement specifications. This should include the airport name, airport location, the FAA specification material and type, and all other pertinent information and test data. Entries for failed tests and retests should also be included.

- It is recommended that a payment adjustment schedule not be made for materials such as:

  P-152, Excavation and Embankment.
  P-209, Crushed Aggregate Base Course.
  P-304, Cement Treated Base Course.

- Since many engineers are currently using nuclear testing for P-152, Excavation and Embankment, it is recommended that the FAA evaluate procedures for the acceptance of nuclear testing.

- Since most engineers are currently measuring form depth in lieu of core testing for concrete, it is recommended that the FAA evaluate acceptable methods for these type inspections. This includes the materials of P-306, Econocrete and P-501, Portland Cement Concrete Pavement. Because of the lack of thickness test data, it is recommended that a thickness-based Payment Adjustment Schedule, on these two items, not be developed at this time.

- Current practice for P-501 Concrete flexural strength is that beams will be broken at 7-days, and if these test results are above the 28-day specification the Contractor may be paid at 100% and the 28-day tests may/may not be performed. It is recommended that a partial payment, at most, be made based on the 7-day tests and a final payment be made after 28-day tests according to Payment Adjustment Schedule calculations.

- Development of a payment adjustment schedule for Item P-501, Portland Cement Concrete Pavement is recommended because sufficient, acceptable test data have been collected and it is desirable to have such a payment adjustment program for this type material. This Payment Adjustment Schedule has been developed into an IBM Compatible computer program that can be used for field entry of test data results.

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APPENDIX A
NORMAL DISTRIBUTION

The normal distribution is actually a family of distributions given by the following function of x ($-\infty < x < \infty$):

$$f(x|\mu,\sigma) = \frac{1}{\sigma(2\pi)^{1/2}} \exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right] \qquad \text{(A-1)}$$

where μ ($-\infty < \mu < \infty$) is the mean of the distribution and σ ($\sigma > 0$) is the standard deviation of the distribution; there is a unique normal distribution corresponding to each choice of μ and σ. The graph of f(x) is symmetrical and bell-shaped, and centered at μ. The spread of the graph is determined by σ and widens as σ increases.

For a given μ and σ, the area under the graph of (A-1) and to the left of L is equal to

$$A = \int_{-\infty}^{L} f(x|\mu,\sigma)\ dX \qquad \text{(A-2)}$$

Due to a special property of the normal distribution, this area is equal to

$$A = \int_{-\infty}^{(L-\mu)/\sigma} f(x|0,1)\ dX \qquad \text{(A-3)}$$

where $f(x|0,1)$ is the standard normal distribution, the normal family member with $\mu = 0$ and $\sigma = 1$. The equality of the areas in (A-2) and (A-3) imply that the area under any normal distribution and to the left of a limit can be found by computing the area under a standard normal distribution and to the left of the original limit transformed.

Another way to refer to the area in (A-3) is $\Phi[(L-\mu)/\sigma]$, where the function $\Phi(\cdot)$ is the area under the standard normal curve and to the left of the argument. This integral is easily evaluated using numerical methods; tables of this integral appear in most statistics books and an abbreviated table appears below as Table A.1. Note that $z = (L-\mu)/\sigma$ and $A = \Phi(z) = \Phi[(L-\mu)/\sigma]$. For example, if $L = 650$, $\mu = 600$, and $\sigma = 48$; $z = 1.04$ and according to Table A.1, the area to the left of 650 is about .85.

z	A
2.326	.99
1.645	.95
1.282	.90
1.037	.85
.842	.80
.675	.75
.524	.70
.385	.65
.253	.60
.126	.55
0	.50
- .126	.45
- .253	.40
- .385	.35
- .524	.30
- .675	.25
- .842	.20
-1.037	.15
-1.282	.10
-1.645	.05
-2.326	.01

TABLE A.1.
STANDARD NORMAL DISTRIBUTION

If one is interested in the area under a normal curve and to the right (rather than left) of a limit, the computations are similar. First note that since the normal curve is symmetric, $\Phi(x) + \Phi(-x) = 1$. Since the area to the right of a limit, plus the area to the left of the same limit, must equal 1, $\Phi(x)$ being the area to the left implies that the area to the right is $\Phi(-x)$. Thus, the area under a normal curve and to the right of a limit is $\Phi[-(L-\mu)/\sigma] = \Phi[(\mu-L)/\sigma]$. For example, if $L = 650$, $\mu = 600$, and $\sigma = 48$; $z = -1.04$ and according to Table A.1, the area to the right of 650 is about .15.

APPENDIX B
DERIVATION OF FORMULAS FOR $EPAL_N$

In this appendix, Equations (B-5) through (B-14) are derived from Equation (3.4) from Page 9. Recall that:

$$EPAL_n = 100 \{ 1 - \int_0^A \text{beta } (X;\, n/2 - 1)\, dX \}, \qquad \text{(B-1)}$$

where $A = \max [0,\ 1/2 - 1/2\ Q\ (n^{1/2}/n-1)]$ and beta $(X;\ n/2 - 1)$ is the beta density with $\alpha = \beta = n/2 - 1$. The beta density is defined for α, $\beta > 0$ and is non-zero for $0 < X < 1$; it is [7]:

$$f(X) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} X^{\alpha-1}\ (1-X)^{\beta-1}. \qquad \text{(B-2)}$$

The following 2 equations are useful in analyzing the gamma function. Note that Equation (B-3) implies that for a positive integer Z, $\Gamma(Z) = (Z-1)!$.

$$\Gamma(Z+1) = Z\ \Gamma(Z) \text{ for } Z > 0 \qquad \text{(B-3)}$$

$$\Gamma(1/2) = \pi^{1/2} \qquad \text{(B-4)}$$

Substituting $\alpha = \beta = n/2 - 1$ into Equation (B-2), and substituting the result into Equation (B-1) produces, for a positive integer n,

$$EPAL_n = 100 \{ 1 - \frac{\Gamma(n-2)}{[\Gamma(n/2 - 1)]^2} \int_0^A (X-X^2)^{n/2-2}\, dX \}. \qquad \text{(B-5)}$$

Since α, $\beta > 0$, n must be greater than 2. For n = 3, from a table of integrals [8] it is found that:

$$\int_0^A (X-X^2)^{-1/2}\, dX = -\text{SIN}^{-1}(1-2A) + \pi/2. \qquad \text{(B-6)}$$

Using Equations (B-6) and (B-5) it is seen that:

$$EPAL_3 = 100\ \{.5 + (1/\pi)\,SIN^{-1}(1-2A)\} \qquad (B-7)$$

which is Equation (4.5) from Page 9. Also from a table of integrals [8] it is found that, for a non-negative integer N,

$$\int_0^A (X-X^2)^{N+1/2}\,dX =$$

$$\frac{(1-2A)(A-A^2)^{N+1/2}}{-4(N+1)} + \frac{(2N+1)}{8(N+1)}\int_0^A (X-X^2)^{N-1/2}\,dX. \qquad (B-8)$$

Letting N + 1/2 = n/2 - 2 we see that N = n/2 - 5/2 is a non-negative integer for n odd and n greater than 3. Substituting the new expression for N into Equation (B-8):

$$\int_0^A (X-X^2)^{n/2-2}\,dX =$$

$$\frac{(1-2A)(A-A^2)^{n/2-2}}{-2(n-3)} + \frac{(n-4)}{4(n-3)}\int_0^A (X-X^2)^{n/2-3}\,dX. \qquad (B-9)$$

Note that the integral on the right hand side of Equation (B-9) can be written in terms of $EPAL_n$-2 by substituting n-2 for n in Equation (B-5) and solving:

$$\int_0^A (X-X^2)^{n/2-3}\,dX = \frac{[\Gamma(n/2\ -\ 2)]^2}{\Gamma(n-4)}\,(1\ -\ EPAL_{n-2}\ /100). \qquad (B-10)$$

Substituting the right hand side of Equation (B-10) into Equation (B-9), and substituting the result into Equation (B-5), it is found that, for n odd and n greater than 3,

$EPAL_n =$

$$100 \left\{ 1 - \frac{\Gamma(n-2)}{[\Gamma(n/2-1)]^2} \left[\frac{(1-2A)(A-A^2)^{n/2-2}}{2(n-3)} + \frac{(n-4)}{4(n-3)} \right.\right.$$

$$\left.\left. \frac{[\Gamma(n/2-2)]^2}{\Gamma(n-4)} (1 - EPAL_{n-2}/100) \right] \right\} \qquad \text{(B-11)}$$

Note that:

$$\frac{\Gamma(n-2)}{[\Gamma(n/2-1)]^2} \frac{(n-4)}{4(n-3)} \frac{[\Gamma(n/2-2)]^2}{\Gamma(n-4)} = 1 \qquad \text{(B-12)}$$

Using Equations (B-11) and (B-12) we get:

$EPAL_n =$

$$100 \left\{ \frac{\Gamma(n-2)}{[\Gamma(n/2-1)]^2} \frac{(1-2A)(A-A^2)^{n/2-2}}{2(3-n)} \right\} + EPAL_{n-2} \qquad \text{(B-13)}$$

Equations (4-7), (4-9), (4-11), and (4-13) from Page 9 follow directly from Equation (B-13).

Using the binomial formula [8], it is found that, for a non-negative integer N,

$$(X-X^2)^N = \sum_{i=0}^{N} (-1)^i \, C(N,i) \, X^{N+i} \qquad \text{(B-14)}$$

where C(N,i) equals the number of unique combinations of N items taken i at a time. Applying the integral to both sides of Equation (B-14):

$$\int_0^A (X-X^2)^N \, dX = \sum_{i=0}^{N} (-1)^i \, C(N,i) \, \frac{A^{N+i+1}}{N+i+1} \qquad \text{(B-15)}$$

Letting $N = n/2 - 2$ it is seen that N is a non-negative integer for n even and n greater than 2. Substituting the new expression for N into Equation (B-15), and the result into Equation (B-5) produces, for n even and n greater than 2,

$$EPAL_n =$$

$$100 \left(1 - \frac{\Gamma(n-2)}{[\Gamma(n/2 - 1)]^2} \sum_{i=0}^{n/2 - 2} (-1)^i \, C(N,i) \, \frac{A^{n/2 + i - 1}}{n/2 + i - 1} \right) \qquad \text{(B-16)}$$

Equations (4-6), (4-8), (4-10), (4-12), and (4-14) from Page 9 follow directly from Equation (B-16).

APPENDIX C
CALCULATION OF THE OC

In this Appendix, a method for calculating the OC corresponding to a particular value of PAL will be presented. This value, OC_{100p}, can be written:

$$OC_{100p} = \Pr\,(EPAL_n < \text{Acceptance Limit} \mid PAL = 100p). \tag{C-1}$$

With respect to the acceptance plan for P-501 Concrete, Equation (C-2) is:

$$OC_{100p} = \Pr\,(EPAL_8 < 73\% \mid PAL = 100p). \tag{C-2}$$

Using the fact that there is a one-to-one correspondence between $EPAL_8$ and Q [Equation (4.10)] Page 9, and the fact that PAL = 100 $\Phi[(\mu-L)/\sigma]$, an equivalent expression for Equation (C-2) is:

$$OC_{100p} = \Pr\,(Q < .6344 \mid (\mu-L)/\sigma = \Phi^{-1}(p)). \tag{C-3}$$

Using an elementary result in probability, all the terms on the right side of Equation (C-3) can be multiplied by a constant resulting in the equivalent expression:

$$OC_{100p} = \Pr\,(8^{1/2}Q < 1.794 \mid 8^{1/2}(\mu-L)/\sigma = 8^{1/2}\Phi^{-1}(p)). \tag{C-4}$$

The probability in Equation (C-4) can be computed using the fact that $n^{1/2}Q$ is distributed as a noncentral t random variable with $\tau = n-1$ degrees of freedom and noncentrality parameter $\delta = n^{1/2}(\mu-L)/\sigma$ [Appendix D]. To simplify the calculations use the fact that the probability that a noncentral t random variable with parameters τ and δ is less than a constant, h, is approximately equal to $\Phi(z)$ where z is computed using Equation (C-5) [9]:

$$z = \frac{h(1 - 1/4\tau) - \delta}{(1 + h^2/2\tau)^{1/2}}. \tag{C-5}$$

For example, for PAL = 80, it is found from a standard normal table that $(\mu-L)/\sigma = 0.842$. This implies that $\delta = 2.382$. Using Equation (C-5) we find that $z = -.588$. Again, using a standard normal table, we find that $OC_{80} = .278$. The OC corresponding to various levels of PAL appear in Table C.1, along with the results of the intermediate calculations.

PAL	$(\mu-L)/\sigma$	δ	z	OC
95	1.645	4.653	-2.636	.004
90	1.282	3.626	-1.710	.044
85	1.036	2.930	-1.082	.140
80	0.842	2.382	-0.588	.278
75	0.674	1.906	-0.159	.437
70	0.524	1.482	0.224	.589
65	0.385	1.089	0.578	.718
60	0.253	0.716	0.914	.820
55	0.126	0.356	1.239	.892

TABLE C.1
OPERATING CHARACTERISTIC FOR GIVEN PAL AND QUALITY LEVELS

Also in this Appendix, a method for computing the overdesign (μ-L) corresponding to a given probability (P) and lot standard deviation (σ) will be presented. This value can be computed using a rewritten form of Equation (C-5):

$$\delta = h(1 - 1/4\tau) - z(1 + h^2/2\tau)^{1/2}. \qquad \text{(C-6)}$$

For example, consider the acceptance plan for P-501 Concrete. Recall that the acceptance value is 73%. Using Equation *(4-10)* Page 9, it is found that the corresponding Q is .6344. Since $h = n^{1}/2(Q)$, h = 1.794. Since $\tau = n-1$, $\tau = 7$. Now for P = .90, z = -1.282. Using Equation (4-17) it is found that $\delta = 3.152$. Since $\delta = n^{1}/2(\mu-L)/\sigma$, $(\mu-L)/\sigma = 1.114$. This relationship allows computing, for a given σ, the $(\mu-L)$ needed to achieve a probability of .90 of acceptance, as in Table 4.4, Page 17. The same is done for P = .95 and P = .99 and the results are presented in Table C.2 along with the results of the intermediate calculations.

P	z	δ	$(\mu-L)/\sigma$
.90	-1.282	3.152	1.114
.95	-1.645	3.554	1.257
.99	-2.326	4.309	1.523

TABLE C.2
QUALITY REQUIRED TO ACHIEVE GIVEN PROBABILITY OF ACCEPTANCE

APPENDIX D
DERIVATION OF THE DISTRIBUTION OF $N^{1/2}$ Q

In this appendix it will be shown that $n^{1/2}Q$ is distributed as a noncentral t random variable with τ = n-1 degrees of freedom and noncentrality parameter $\delta = n^{1/2}(\mu-L)/\sigma$. Recall that:

$$Q = \frac{\bar{X}-L}{S} \tag{D-1}$$

A noncentral t random variable with τ degrees of freedom and noncentrality parameter δ is defined as the ratio of a normal random variable with mean δ and standard deviation 1, and the square root of a chi-square random variable divided by its degrees of freedom τ [4].

First note that [4]:

$$\frac{\bar{X}-\mu}{\sigma/n^{1/2}} \in N(0,1). \tag{D-2}$$

This implies that:

$$\frac{\bar{X}-\mu}{\sigma/n^{1/2}} + \frac{\mu-L}{\sigma/n^{1/2}} = \frac{\bar{X}-L}{\sigma/n^{1/2}} \in N(\delta,1), \tag{D-3}$$

where δ equals $n^{1/2}(\mu-L)/\sigma$. Also note that [4]:

$$\frac{(n-1)S^2}{\sigma} \in \text{Chi-square } (n-1). \tag{D-4}$$

Dividing the random variable by its degrees of freedom and taking the square root:

$$\left[\frac{(n-1)S^2}{\sigma(n-1)}\right]^{1/2} = \frac{S}{\sigma}. \qquad \text{(D-5)}$$

Dividing the $N(\delta,1)$ random variable in Equation (D-3) by the right hand side of Equation (D-5):

$$n^{1/2}\,\frac{\overline{X}-L}{S} \qquad \text{(D-6)}$$

which, by definition, is a noncentral t random variable with τ = n-1 degrees of freedom and noncentrality parameter $\delta = n^{1/2}(\mu-L)/\sigma$.

APPENDIX E
ERROR CODES

TABLE E.1

Code	Decsription	Code	Description
2	Syntax error	53	File not found
3	RETURN without GOSUB	54	Bad file mode
4	Out of DATA	55	File already open
5	Illegal function call	56	FIELD statement active
6	Overflow	57	Device I/O error
7	Out of memory	58	File already exists
9	Subscript out of range	59	Bad record length
10	Duplicate definition	61	Disk full
11	Division by zero	62	Input past end of file
13	Type mismatch	63	Bad record number
14	Out of string space	64	Bad file name
16	String formula too complex	67	Too many files
19	No RESUME	68	Device unavailable
20	RESUME without error	69	Communication-buffer overflow
24	Device Timeout	70	Permission denied
25	Device fault	71	Disk not ready
27	Out of paper	72	Disk-media error
39	CASE ELSE expected	73	Advanced feature unavailable
40	Variable required	74	Rename across disks
50	FIELD overflow	75	Path/File access error
51	Internal Error	76	Path not found
52	Bad file name or number		

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APPENDIX F
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Sally Jo Nguyen

Sally Nguyen
Law and Corporate Affairs

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APPENDIX G
SAMPLE OF dBASE III FILENAMES

P-501, PORTLAND CEMENT CONCRETE PAVEMENT (FLEXURAL STRENGTH AND THICKNESS)

ACY501A	FAA TECH CENTER, FLEX '85
ACY501B	FAA TECH CENTER, '85 (THICKNESS)
BUF501A	GREATER BUFFALO INTERNAT '86
BUF501B	GREATER BUFFALO INTERNAT
BUF501C	GREATER BUFFALO INTERNAT '74-75
BUF501D	GREATER BUFFALO INTERNAT '86 (THICKNESS)
BWI501A	BALTIMORE WASHINGTON INT '84-85
CHO501A	CHARLOTTESVILLE-ALBERMARLE, VA. '84
IAD501A	DULLES INTERNATIONAL '86
IAG501A	NIAGARA FALLS INT. AIRPORT '85
IAG501B	NIAGARA FALLS INT. AIRPORT
ORF501A	NORFOLK INTERNATIONAL '87
ORF501B	NORFOLK INTERNATIONAL '84
PHF501A	PATRICK HENRY AIRPORT '75
PHL501A	PHILADELPHIA INTERNATIONAL '87
PIT501A	GREATER PITTSBURGH
PIT501B	GREATER PITTSBURGH (THICKNESS)
PIT501C	GREATER PITTSBURGH '86
PIT501D	GREATER PITTSBURGH '86 (THICKNESS)
ROC501A	ROCHESTER MONROE COUNTY '83
SBY501A	WICOMICO COUNTY AIRPORT '85
SYR501A	HANCOCK INT - SYRACUSE '80
SYR501B	HANCOCK INT - SYRACUSE '82

APPENDIX H
P-501 TEST DATA PRINTOUT SAMPLE

FAA ACCEPTANCE AND PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENTS
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 1

****

Airport: Norfolk International Airport
Norfolk, VA
ORF

Consultant/Engineer: R. Kenneth Weeks, Engineers
Norfolk, VA

Construction Contractor: Williams Corp. of Va.
Norfolk, VA

Pavement Testing Laboratory: ATEL Associates of Va., Inc.
Norfolk, VA

****

FAA Contract Number: AIP #3-51-0036-06
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

****

Pavement Specification: P-501, PORTLAND CEMENT CONCRETE PAVEMENT
Design Target Specification in PSI: 700

****

Method of Testing: Flexural Strength Beams
ASTM Number: ASTM-C-78

****

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
1	Lane #1, north end at 0+80	11/24/87	12/22/87	28
2	Lane #1, north end	11/24/87	12/22/87	28
3	Lane #3, north end at 0+80	11/25/87	12/23/87	28
4	Lane #3, north end at 0+330	11/25/87	12/23/87	28
5	Lane #5, north end	11/30/87	12/28/87	28
6	0+330 Ft	11/30/87	12/28/87	28
7	Lane #7, north end at 0+80	12/02/87	12/30/87	28
8	north end at 0+240	12/03/87	01/05/88	33
9	Lane #9, north end, 0+130 yards	12/07/87	01/05/88	29
10	Lane #9, north end 0+370	12/07/87	01/05/88	29

****

LOT NO.	-------TEST RESULT STRENGTH IN PSI-------- # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
1	655	660	705	710	0	0	683	29.011	-0.603	29.9	0.0
2	775	750	795	785	0	0	776	19.311	3.949	100.0	100.0
3	720	715	810	890	0	0	784	83.204	1.007	83.6	94.1
4	720	710	785	790	0	0	751	42.106	1.217	90.6	100.0
5	675	730	735	780	0	0	730	43.012	0.697	73.2	79.2
6	745	740	765	807	0	0	764	30.478	2.108	100.0	100.0
7	750	720	770	810	0	0	763	37.749	1.656	100.0	100.0
8	730	764	815	830	0	0	785	46.155	1.836	100.0	100.0
9	730	740	760	795	0	0	756	28.687	1.961	100.0	100.0
10	780	750	815	800	0	0	786	28.100	3.069	100.0	100.0

APPENDIX H (Continued)
P-501 TEST DATA PRINTOUT SAMPLE

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 2

****

Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

****

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
11	3rd slab from west, 66' from north to south	12/08/87	01/05/88	28
12	3rd slab from west, 254' from north to south	12/08/87	01/05/88	28
13	Lane #11, North end 0+250 yds	12/10/87	01/07/88	28
14	Lane #11, north end, 0+410 ft	12/10/87	01/07/88	28
15	Lane #11, north end, 0+90	12/11/87	01/08/88	28
16	Lane #11	12/11/87	01/08/88	28
17	Lane #2, near runway, north end 0+100	12/12/87	12/26/87	14
18	Lane #2, north end 0+320	12/12/87	12/26/87	14
19	Lane #4, north end, 0+115 ft	12/14/87	12/28/87	14
20	Lane #4, north end 0+390 ft	12/14/87	12/28/87	14
21	Lane #6, north end 0+130 ft	12/16/87	01/13/88	28
22	Lane #6, 0+390	12/16/87	01/13/88	28
23	Lane #8, north end, 0+95 ft	12/17/87	01/14/88	28
24	Lane #8, 0+245 ft	12/18/87	01/15/88	28
25	Lane #8, 0+366 ft	12/18/87	01/15/88	28

****

LOT	-------TEST	RESULT	STRENGTH	IN PSI--------				STD	EST	EST	% PAY
NO.	# 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	DEV	QL	PWL	FACTOR
11	695	680	735	755	0	0	716	34.731	0.468	65.6	63.7
12	725	700	810	850	0	0	771	70.519	1.010	83.7	94.3
13	735	716	790	830	0	0	768	52.028	1.302	93.4	100.0
14	695	695	750	720	0	0	715	26.141	0.574	69.1	71.3
15	725	669	780	760	0	0	734	48.638	0.689	73.0	78.7
16	675	750	730	810	0	0	741	55.734	0.740	74.7	81.7
17	585	620	670	670	0	0	636	41.508	-1.536	0.0	0.0
18	660	640	720	725	0	0	686	42.696	-0.322	39.3	0.0
19	640	620	715	684	0	0	665	42.859	-0.822	22.6	0.0
20	675	655	745	700	0	0	694	38.810	-0.161	44.6	0.0
21	670	720	760	790	0	0	735	51.962	0.674	72.5	77.8
22	670	712	790	710	0	0	721	50.210	0.408	63.6	59.1
23	775	745	760	770	0	0	763	13.229	4.725	100.0	100.0
24	710	740	795	780	0	0	756	38.595	1.457	98.6	100.0
25	830	880	940	955	0	0	901	57.500	3.500	100.0	100.0

APPENDIX H (Continued)
P-501 TEST DATA PRINTOUT SAMPLE

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 3

****

Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

****

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
26	Lane #8, north end 0+150 ft	12/21/87	01/18/88	28
27	Lane #10, north end, 3+35	01/04/88	02/01/88	28
28	Lane #10, from 0+00 to 0+50	01/13/88	02/10/88	28
29	Lane #12, north end 100+30 ft	01/19/88	02/16/88	28
30	Lane #12, north end, 3+10 ft	01/19/88	02/16/88	28
31	Lane #12, north end, 4+10 ft	01/21/88	02/04/88	14
32	Lane #14, east end, 1+10 ft	01/22/88	02/19/88	28
33	Area #2, center cross lane, seq. #2	02/01/88	02/29/88	28
34	Lane #2, area #3, east end, 0+85 ft	02/09/88	03/08/88	28
35	Lane #2, area #3, east end, 1+95 ft	02/09/88	03/08/88	28
36	Lane #4, south side, east end, 0+85 ft	02/10/88	03/09/88	28
37	Lane #4, area #3, south side, east end 1+98 ft	02/10/88	03/09/88	28
38	Area #2, lane #3, east end 0+95	02/15/88	03/14/88	28
39	Lane #3, area #2, east end, 1+15 ft	02/17/88	03/16/88	28
40	Area #2, Lane #4, East of 3=40'	02/17/88	03/16/88	28

****

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
26	710	720	790	740	0	0	740	35.590	1.124	87.5	98.0
27	720	700	695	745	0	0	715	22.730	0.660	72.0	76.9
28	720	770	830	810	0	0	783	48.563	1.699	100.0	100.0
29	759	750	825	790	0	0	781	33.971	2.384	100.0	100.0
30	662	638	720	740	0	0	690	47.917	-0.209	43.0	0.0
31	600	640	760	760	0	0	690	82.462	-0.121	46.0	0.0
32	750	670	745	770	0	0	734	43.851	0.770	75.7	83.3
33	670	690	810	880	0	0	763	99.791	0.626	70.9	74.8
34	875	790	860	880	0	0	851	41.708	3.626	100.0	100.0
35	720	730	810	810	0	0	768	49.244	1.371	95.7	100.0
36	700	685	760	785	0	0	733	47.697	0.681	72.7	78.2
37	710	710	780	770	0	0	743	37.749	1.126	87.5	98.1
38	700	730	825	805	0	0	765	59.582	1.091	86.4	97.0
39	770	760	830	800	0	0	790	31.623	2.846	100.0	100.0
40	720	760	780	850	0	0	778	54.391	1.425	97.5	100.0

APPENDIX I
CURVE DEFAULT PROGRAM

The [FAACURVE] program was designed to permit FAA office personnel to change the defaults from airport to airport.

This program flow is as follows:

1. Load MS-DOS into computer.

2. Enter [A:] to transfer to A: Drive.

3. Insert OFFICE FAA-PAP disk into Drive A, type [FAASTART] and press [ENTER] key. From the Introduction Screen, type [CURVE] and press the [ENTER] key.

4. Screen 1 Figure I.1 will appear, explaining this program is restricted to FAA trained personnel only. Press any key to continue.

5. Screen 2 Figure I.2 will appear permitting FAA personnel to specify the airport, consultant and the specific contract the defaults will apply to. Press [Y] to continue.

6. Screen 3 Figure I.3 will appear permitting selecting of the design target specification. This screen is also a menu. Selecting [2] will load PAP programs and selecting [3] will return to MS-DOS.

7. The default selection and calculation Screen 4, Figure I.4 will appear. Selecting a default point by number, [1] through [3], will permit changing a default as follows:

   [1] Point 1-All PAL above will receive 100% payment.
   [2] Point 2-All PAL below will not receive any payment.
   [3] Scaling Factor [1] is the least severe penalty. [0] is the most severe penalty (straight line). [.6] is a good selection.

   For Points 1 and 2, enter PAL as a percent between 100 to 0.

   For Scaling Factor 3, enter as a decimal between 1.0 to 0.

   After entering a new amount, the program will calculate and display a new pay factor formula and several PAL/Pay Factor points on the proposed curve for the operator's review and approval. This process can be continued until the operator is satisfied with the results. At this point, the operator must enter [S] to save the default values he has selected and wants to use for this airport project.

FAA PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENT CONSTRUCTION
SELECTION OF FORMULA DEFAULTS

****

NOTE: THIS PROGRAM IS FOR USE BY FEDERAL AVIATION ADMINISTRATION TRAINED AND AUTHORIZED OFFICE PERSONNEL ONLY.

This program modifies the defaults in the pay adjustment schedules for specific airport construction projects.

Minor changes inputing default points can cause drastic changes and errors in the pay factor formula.

PRESS [X] TO EXIT TO DOS - OR - [S] TO OPERATE THE PAP PROGRAM
- OR - ANY OTHER KEY TO CONTINUE WITH THIS PROGRAM.
RESPONSE REQUEST MODE

FIGURE I.1
SCREEN 1

```
        FAA PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENT CONSTRUCTION
                     SELECTION OF FORMULA DEFAULTS
********************************************************************************
1. Airport: Norfolk International Airport
            Norfolk, VA
            ORF
********************************************************************************
2. Consultant/Engineer: R. Kenneth Weeks, Engineers
                        Norfolk, VA
********************************************************************************
3. FAA Contract Number: AIP #3-51-0036-06
   FAA Project Name: Terminal Apron Expansion
********************************************************************************
4. FAA Material
       Specification: P-501, PORTLAND CEMENT CONCRETE PAVEMENT


       IS THE INFORMATION LISTED ABOVE CORRECT  [Y]  FOR YES
     OR ENTER THE NUMBER CORRESPONDING TO REQUIRED CORRECTION
                   RESPONSE REQUEST MODE
```

FIGURE I.2
SCREEN 2

```
          FAA PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENT CONSTRUCTION
                      SELECTION OF FORMULA DEFAULTS
********************************************************************************

   1. P-501, PORTLAND CEMENT CONCRETE PAVEMENT

********************************************************************************

   2. LOAD PAP PROGRAMS AND FILES.

   3. EXIT THIS PROGRAM TO MS-DOS.

********************************************************************************

   4. DESIGN TARGET SPECIFICATION IN PSI: 700



         ENTER THE DESIRED DESIGN TARGET SPECIFICATION IN PSI <700>:

                              INPUT MODE
```

FIGURE I.3
SCREEN 3

```
            FAA PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENT CONSTRUCTION
                    P-501, PORTLAND CEMENT CONCRETE PAVEMENT
********************************************************************************
1.  THE LOWEST PWL IN PERCENT TO RECEIVE 100% PAYMENT:  90
2.  THE LOWEST PWL IN PERCENT TO RECEIVE MINIMUM PAYMENT:  60
    THE MINIMUM PAY FACTOR IN PERCENT TO RECEIVE PAYMENT:  50
3.  THE MIDPOINT SCALING FACTOR BETWEEN [1] AND [-1]:  .6
********************************************************************************
PAY FACTOR FORMULA IS: -3.212007 *PWL^2 +  6.484677 *PWL + -2.234484
********************************************************************************
PAY FACTOR CURVE POINTS BASED ON ABOVE INPUT POINTS:
POINT A - ABOVE  90 % PWL IS 100 % PAYMENT.
 85 % PWL = 95.68 % PAY FACTOR
 80 % PWL = 89.76 % PAY FACTOR
 75 % PWL = 82.23 % PAY FACTOR
 70 % PWL = 73.09 % PAY FACTOR
 65 % PWL = 62.35 % PAY FACTOR
 60 % PWL = 50.00 % PAY FACTOR
POINT B - BELOW  60 % PWL IS ZERO PAYMENT.

         ENTER THE NUMBER CORRESPONDING TO THE REQUIRED CORRECTION POINT
            - OR - ENTER  [S]  TO SAVE - OR - [M]  TO RETURN TO MENU
                          RESPONSE REQUEST MODE
```

FIGURE I.4
SCREEN 4

8. Entering a [M] will return the program to the Material Selection Screen, Screen 3,

9. The operator can enter [2] to return to the PAP program,
   OR
   Enter [3] to EXIT to MS-DOS.

10. The operator can now generate a FIELD FAA-PAP disk. This disk will be used at the construction site to enter information and pavement test data.

11. Insert a formatted disk, without any files on it, into Drive B.

12 Computer must be at MS-DOS level with the A> prompt and the OFFICE FAA-PAP disk be inserted into Drive A.

13. Type [DISKCOPY A: B:] and press the [ENTER] key. Required files will COPY from the office disk to the field disk. Type [DEL B:FAACURVE.EXE] and press the [ENTER] key to remove the FAACURVE file from the Field disk.

14. Make backup copy of the new FIELD FAA-PAP disk by DISKCOPY command.

15. Label the new FIELD FAA-PAP as follows:

    FIELD INFORMATION AND DATA for (airport and city/state)

    Enter FAASTART to run program.

    DATE: (Use date Field program was made).

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APPENDIX J
PAP TEST RESULTS - GREATER PITTSBURGH INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT DEFAULTS FOR AIRPORT PAVEMENT CONSTRUCTION
P-501, Portland Cement Concrete Pavement
for Greater Pittsburgh International Airport

****

1. THE LOWEST PWL IN PERCENT TO RECEIVE 100% PAYMENT: 90

2. THE LOWEST PWL IN PERCENT TO RECEIVE MINIMUM PAYMENT: 60
   THE MINIMUM PAY FACTOR IN PERCENT TO RECEIVE PAYMENT: 50

3. THE MIDPOINT SCALING FACTOR BETWEEN [1] AND [-1]: .6

****

PAY FACTOR FORMULA IS: -3.212007 *PWL^2 + 6.484677 *PWL + -2.234484

****

Press any key to return to program.
RESPONSE REQUEST MODE

APPENDIX J (Continued)
PAP TEST RESULTS - GREATER PITTSBURGH INTERNATIONAL AIRPORT

FAA ACCEPTANCE AND PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENTS
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 1

****

Airport: Greater Pittsburgh International Airport
Pittsburgh, PA
PIT

Consultant/Engineer:

Construction Contractor: Trumbull

Pavement Testing Laboratory: ACDA

****

FAA Contract Number: 7758
FAA Project Name: Midfield Terminal Project
Work Area Project Name: BP-02 N/S Taxiways and Tunnel

****

Pavement Specification: P-501, Portland Cement Concrete Pavement
Design Target Specification in PSI: 750

****

Method of Testing: Flexural Beam
ASTM Number:

****

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
1	TW-A2 next to taxiway	08/15/89	09/12/89	28
2	TW-A2 Lane next to existing taxiway	08/15/89	09/12/89	28
3	TW-F Sta 13+90 to 34+25, CL to 25' left	08/16/89	09/13/89	28
4	TW-F Sta 13+90 to 34+25, CL to 25' left	08/16/89	09/13/89	28
5	TW-A N-1 A2 Stub Sta 21+00 to 21+50	08/17/89	09/14/89	28
6	TW-F Sta 34+25 & TW-D Sta 42+50	08/18/89	09/15/89	28
7	TW-F Sta 34+25 & TW-D Sta 42+50	08/18/89	09/15/89	28
8	TW-D Sta 28+50 to 14+00, CL to 25' right	08/21/89	09/18/89	28
9	TW-D Sta 28+50 to 14+00, CL to 25' right	08/21/89	09/18/89	28
10	TW-F Sta 13+00 to 34+25, CL to 25' right	08/22/89	09/19/89	28

****

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
1	760	755	760	745	0	0	755	7.071	0.707	73.6	79.8
2	770	750	785	745	0	0	763	18.484	0.676	72.5	77.9
3	775	750	750	755	0	0	758	11.902	0.630	71.0	75.1
4	765	750	760	780	0	0	764	12.500	.100	86.7	97.3
5	770	760	740	780	760	765	763	13.323	0.938	82.0	92.4
6	730	790	700	820	0	0	760	54.772	0.183	56.1	0.0
7	745	755	765	750	0	0	754	8.539	0.439	64.6	61.5
8	945	920	1000	1010	0	0	969	43.277	5.055	100.0	100.0
9	890	910	865	890	0	0	889	18.428	7.529	100.0	100.0
10	950	905	880	890	0	0	906	30.923	5.053	100.0	100.0

APPENDIX J (Continued)
PAP TEST RESULTS - GREATER PITTSBURGH
INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 2

Airport: Greater Pittsburgh International Airport, Pittsburgh, PA
FAA Project Name: Midfield Terminal Project
Work Area Project Name: BP-02 N/S Taxiways and Tunnel

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
11	TW-A Sta 20+75, 21+25 & 21+75	08/22/89	09/19/89	28
12	TW-F Sta 34+25 to 42+50, CL to 25' right	08/23/89	09/20/89	28
13	TW-D Sta 42+50 to 29+00, CL to 25' left	08/23/89	09/20/89	28
14	TW-D Sta 29+00 to 14+00, CL to 25' left	08/24/89	09/21/89	28
15	TW-D Sta 29+00 to 14+00, CL to 25' left	08/24/89	09/21/89	28
16	TW-W Sta 12+75 to 13+75, D-F tie in	08/25/89	09/22/89	28
17	TW-W Sta 12+75, 13+25 & 13+75	08/25/89	09/22/89	28
18	TW-A Sta 98+11 to 124+36, CL to 25' left	08/26/89	09/23/89	28
19	TW-A Sta 98+11 to 124+36, CL to 25' left	08/26/89	09/23/89	28
20	TW-W Sta 13+00 to 14+75, D-F tie in	08/28/89	09/25/89	28
21	TW-W Sta 13+00 to 14+75, D-F tie in	08/28/89	09/25/89	28
22	TW-R&W, D-F tie in	08/29/89	09/26/89	28
23	TW-R&W, D-F tie in	08/29/89	09/26/89	28
24	TW-W Sta 14+00 to 15+00, D-F tie in	08/30/89	09/27/89	28
25	TW-W Sta 14+00 to 15+00, D-F tie in	08/30/89	09/27/89	28

LOT NO.	-------TEST RESULT STRENGTH IN PSI-------- # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
11	930	935	975	905	0	0	936	28.976	6.428	100.0	100.0
12	985	920	890	895	950	950	932	36.696	4.951	100.0	100.0
13	875	850	850	950	0	0	881	47.324	2.773	100.0	100.0
14	775	930	965	935	0	0	901	85.574	1.767	100.0	100.0
15	855	870	930	995	0	0	913	63.836	2.546	100.0	100.0
16	870	905	1025	865	0	0	916	74.652	2.227	100.0	100.0
17	930	960	925	865	0	0	920	39.791	4.272	100.0	100.0
18	1025	1140	1080	1030	0	0	1069	53.599	5.947	100.0	100.0
19	905	1065	890	1015	0	0	969	84.988	2.574	100.0	100.0
20	805	725	830	845	0	0	801	53.444	0.959	82.0	92.3
21	920	885	890	780	0	0	869	61.152	1.942	100.0	100.0
22	800	815	830	815	0	0	815	12.247	5.307	100.0	100.0
23	865	870	760	815	0	0	828	51.397	1.508	100.0	100.0
24	905	915	1000	830	0	0	913	69.582	2.335	100.0	100.0
25	810	825	745	1015	0	0	849	116.145	0.850	78.3	87.4

APPENDIX J (Continued)
PAP TEST RESULTS - GREATER PITTSBURGH INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 3

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Airport: Greater Pittsburgh International Airport, Pittsburgh, PA
FAA Project Name: Midfield Terminal Project
Work Area Project Name: BP-02 N/S Taxiways and Tunnel

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
26	TW-F Sta 39+00 to 15+00	08/31/89	09/28/89	28
27	TW-F Sta 39+00 to 15+00	08/31/89	09/28/89	28
28	TW-F Sta 37+50	09/02/89	09/30/89	28
29	TW-F Sta 37+50	09/02/89	09/30/89	28
30	TW-D Sta 42+00 to 15+00	09/05/89	10/03/89	28
31	TW-D Sta 42+00 to 15+00	09/05/89	10/03/89	28
32	TW-D Sta 13+00 to 42+00, 25' to 37' left	09/06/89	10/04/89	28
33	TW-D Sta 13+00 to 42+00	09/06/89	10/04/89	28
34	TW-A Sta 98+00 to 124+00, CL to 25' right	09/07/89	10/05/89	28
35	TW-A Sta 98+00 to 124+00, CL to 25' right	09/07/89	10/05/89	28
36	TW-A Sta 98+00 to 124+00, CL to 25' left	09/08/89	10/06/89	28
37	TW-A Sta 98+00 to 124+00, CL to 25' left	09/08/89	10/06/89	28
38	TW-A Sta 124+00 to 129+00, CL to 25' right	09/09/89	10/07/89	28
39	TW-A Sta 124+00 to 129+00, CL to 25' right	09/09/89	10/07/89	28
40	TW-A Sta 98+00 to 129+10, 25' to 37' right	09/11/89	10/09/89	28

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LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
26	905	865	910	905	0	0	896	20.966	6.976	100.0	100.0
27	890	900	910	935	0	0	909	19.311	8.221	100.0	100.0
28	905	815	865	890	0	0	869	39.449	3.010	100.0	100.0
29	930	825	890	935	0	0	895	50.827	2.853	100.0	100.0
30	755	840	885	865	0	0	836	57.209	1.508	100.0	100.0
31	855	825	905	930	0	0	879	47.500	2.711	100.0	100.0
32	910	980	920	895	0	0	926	37.277	4.728	100.0	100.0
33	950	920	950	0	0	0	940	17.321	10.970	100.0	100.0
34	760	785	870	715	0	0	783	65.128	0.499	66.6	66.0
35	780	805	885	865	0	0	834	49.392	1.696	100.0	100.0
36	775	780	785	0	0	0	780	5.000	6.000	100.0	100.0
37	785	765	855	770	0	0	794	41.708	1.049	85.0	95.6
38	795	810	810	810	0	0	806	7.500	7.500	100.0	100.0
39	815	790	810	795	0	0	803	11.902	4.411	100.0	100.0
40	720	715	760	800	0	0	749	39.660	-0.032	48.9	0.0

APPENDIX J (Continued)
PAP TEST RESULTS - GREATER PITTSBURGH
INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 4

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Airport: Greater Pittsburgh International Airport, Pittsburgh, PA
FAA Project Name: Midfield Terminal Project
Work Area Project Name: BP-02 N/S Taxiways and Tunnel

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
41	TW-A Sta 98+00 to 129+10, 25' to 37 right	09/11/89	10/09/89	28
42	TW-D & F Sta 15+10 to 18+00	09/12/89	10/10/89	28
43	TW-D & F Sta 15+10 to 18+00	09/12/89	10/10/89	28
44	TW-D1 Sta 16+75 to 17+75	09/13/89	10/11/89	28
45	TW-D1 Sta 16+75 to 17+75	09/13/89	10/11/89	28
46	TW-D2 Sta 24+00 to 26+50	09/14/89	10/12/89	28
47	TW-D2 Sta 24+00 to 26+50	09/14/89	10/12/89	28
48	TW-D2 Sta 24+50 to 25+25	09/15/89	10/13/89	28
49	TW-D2 Sta 24+50 to 25+25	09/15/89	10/13/89	28
50	TW-A Sta 124+50 to 127+50	09/18/89	10/16/89	28
51	TW-A Sta 124+50 to 127+50	09/18/89	10/16/89	28
52	TW-D6 Sta 29+25 to 40+50	09/19/89	10/17/89	28
53	TW-D6 Sta 29+25 to 40+50	09/19/89	10/17/89	28
54	TW-D4 Sta 33+75 to 36+00	09/20/89	10/18/89	28
55	TW-D4 Sta 33+75 to 36+00	09/20/89	10/18/89	28

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LOT	-------TEST	RESULT	STRENGTH	IN PSI	--------			STD	EST	EST	% PAY
NO.	# 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	DEV	QL	PWL	FACTOR
41	800	760	825	765	0	0	788	30.687	1.222	90.7	100.0
42	795	800	910	860	0	0	841	54.524	1.674	100.0	100.0
43	805	815	810	810	0	0	810	4.082	14.690	100.0	100.0
44	830	825	870	795	0	0	830	30.822	2.596	100.0	100.0
45	745	755	805	835	0	0	785	42.426	0.825	77.5	86.2
46	835	840	735	775	0	0	796	50.394	0.918	80.6	90.5
47	840	810	910	910	0	0	868	50.580	2.323	100.0	100.0
48	870	900	845	975	0	0	898	56.347	2.618	100.0	100.0
49	860	920	760	835	0	0	844	66.254	1.415	97.2	100.0
50	735	820	785	815	0	0	789	39.025	0.993	83.1	93.6
51	735	815	810	795	0	0	789	36.827	1.052	85.1	95.8
52	730	735	765	830	0	0	765	46.007	0.326	60.9	52.3
53	810	710	780	775	0	0	769	42.106	0.445	64.8	62.0
54	810	850	840	805	0	0	826	22.127	3.446	100.0	100.0
55	745	740	815	760	0	0	765	34.400	0.436	64.5	61.3

APPENDIX J (Continued)
PAP TEST RESULTS - GREATER PITTSBURGH
INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 5

Airport: Greater Pittsburgh International Airport, Pittsburgh, PA
FAA Project Name: Midfield Terminal Project
Work Area Project Name: BP-02 N/S Taxiways and Tunnel

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
56	TW-D & F Sta 25+50 to 26+75	09/21/89	10/19/89	28
57	TW-D & F Sta 25+50 to 26+75	09/21/89	10/19/89	28
58	TW-A2 Sta 22+25 to 23+25	09/22/89	10/20/89	28
59	TW-A, D & F	09/25/89	10/23/89	28
60	TW-A, D & F	09/25/89	10/23/89	28
61	TW A, D & F	09/26/89	10/24/89	28
62	TW A, D & F	09/27/89	10/25/89	28
63	TW A, D & F	09/27/89	10/25/89	28
64	TW-D & F Sta 41+50 to 43+25	09/28/89	10/26/89	28
65	TW A Sta 110+25 to 112+25	09/29/89	10/27/89	28
66	TW A Sta 100+25 to 112+25	09/29/89	10/27/89	28
67	TW-A Sta 108+00 to 116+00	09/30/89	10/28/89	28
68	TW-A Sta 108+00 to 116+00	09/30/89	10/28/89	28
69	Apron Sta 104+62 to 113+11	10/04/89	11/01/89	28
70	Apron Sta 104+62 to 133+11	10/04/89	11/01/89	28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
56	750	755	765	750	0	0	755	7.071	0.707	73.6	79.8
57	755	745	790	770	0	0	765	19.579	0.766	75.5	83.1
58	810	780	830	780	0	0	800	24.495	2.041	100.0	100.0
59	845	890	755	755	0	0	811	67.500	0.907	80.2	90.1
60	695	820	810	735	0	0	765	60.139	0.249	58.3	0.0
61	810	905	745	835	900	810	834	60.779	1.385	93.1	100.0
62	765	670	755	810	0	0	750	58.452	0.000	50.0	0.0
63	720	815	1025	870	0	0	858	127.704	0.842	78.1	87.0
64	860	900	790	750	0	0	825	67.577	1.110	87.0	97.6
65	1010	890	845	815	0	0	890	85.732	1.633	100.0	100.0
66	720	790	810	800	0	0	780	40.825	0.735	74.5	81.4
67	810	830	790	770	0	0	800	25.820	1.936	100.0	100.0
68	930	790	980	830	0	0	883	87.702	1.511	100.0	100.0
69	805	785	765	815	0	0	793	22.174	1.917	100.0	100.0
70	695	880	840	815	0	0	808	79.635	0.722	74.1	80.6

APPENDIX J (Continued)
PAP TEST RESULTS - GREATER PITTSBURGH
INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 6

Airport: Greater Pittsburgh International Airport, Pittsburgh, PA
FAA Project Name: Midfield Terminal Project
Work Area Project Name: BP-02 N/S Taxiways and Tunnel

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
71	Offset Sta 104+62 to 113+11	10/05/89	11/02/89	28
72	Offset Sta 104+62 to 113+11	10/05/89	11/02/89	28
73	Apron Sta 104+62 to 113+11	10/06/89	11/03/89	28
74	Apron Sta 104+62 to 113+11	10/06/89	11/03/89	28
75	TW-A Sta 23+63	10/07/89	11/04/89	28
76	TW-A Sta 23+63	10/07/89	11/04/89	28
77	Staging Sta 104+62 to 113+11	10/09/89	11/06/89	28
78	Staging Sta 104+62 to 113+11	10/09/89	11/06/89	28
79	Staging Sta 107+98 to 113+11	10/10/89	11/07/89	28
80	Staging Lanes 4 & 6	10/11/89	11/08/89	28
81	Staging Lanes 4 & 6	10/11/89	11/08/89	28
82	Staging Lanes 8 & 10	10/12/89	11/09/89	28
83	Staging Lanes 8 & 10	10/12/89	11/09/89	28
84	Staging Lane 12	10/13/89	11/10/89	28
85	Staging Lane 12	10/13/89	11/10/89	28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
71	680	860	850	900	0	0	823	97.425	0.744	74.8	81.9
72	760	930	860	730	0	0	820	92.014	0.761	75.4	82.8
73	705	807	780	740	0	0	758	44.788	0.179	56.0	0.0
74	710	860	900	840	0	0	828	82.209	0.943	81.4	91.6
75	800	810	830	830	0	0	818	15.000	4.500	100.0	100.0
76	820	800	790	750	0	0	790	29.439	1.359	95.3	100.0
77	860	1020	850	950	0	0	920	80.416	2.114	100.0	100.0
78	810	880	900	740	0	0	833	72.744	1.134	87.8	98.3
79	790	910	760	760	795	795	802	55.557	0.930	81.8	92.1
80	755	680	810	870	0	0	779	80.868	0.356	61.9	54.8
81	730	770	840	860	0	0	800	60.553	0.826	77.5	86.2
82	740	790	800	830	0	0	790	37.417	1.069	85.6	96.3
83	820	840	780	730	0	0	793	48.563	0.875	79.2	88.6
84	738	840	750	775	0	0	776	45.522	0.566	68.9	70.8
85	850	935	795	740	0	0	830	83.167	0.962	82.1	92.4

APPENDIX J (Continued)
PAP TEST RESULTS - GREATER PITTSBURGH
INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 7

Airport: Greater Pittsburgh International Airport, Pittsburgh, PA
FAA Project Name: Midfield Terminal Project
Work Area Project Name: BP-02 N/S Taxiways and Tunnel

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
86	Staging Lane 14 Sta 109+11 to 104+64	10/14/89	11/11/89	28
87	Staging Lane 14 Sta 109+11 to 104+62	10/14/89	11/11/89	28
88	TW-A Sta 45+12 to 43+37	10/16/89	11/13/89	28
89	TW-A Sta 45+12 to 43+37	10/16/89	11/13/89	28
90	TW-W & Staging	10/17/89	11/14/89	28
91	TW-W & Staging	10/17/89	11/14/89	28
92	Station 43+34 to 44+89	10/18/89	11/15/89	28
93	TW-A3 Lane A6	10/20/89	11/17/89	28
94	TW-A3 Lane A6	10/20/89	11/17/89	28
95	TW-A Sta 112+50	10/21/89	11/18/89	28
96	D & A Connection	10/23/89	11/20/89	28
97	D & A Connection	10/23/89	11/20/89	28
98	TW-A Tie in	10/24/89	11/21/89	28
99	TW-A Tie in	10/24/89	11/21/89	28
100	TW-D & F Sta 124+50	10/25/89	11/22/89	28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
86	840	810	830	790	0	0	818	22.174	3.044	100.0	100.0
87	770	790	845	780	0	0	796	33.510	1.380	96.0	100.0
88	835	745	695	845	0	0	780	72.342	0.415	63.8	59.6
89	730	930	765	720	0	0	786	97.756	0.371	62.4	56.0
90	860	850	1000	795	0	0	876	87.309	1.446	98.2	100.0
91	950	810	890	875	0	0	881	57.500	2.283	100.0	100.0
92	840	740	850	780	0	0	803	51.881	1.012	83.7	94.3
93	780	805	885	950	0	0	855	77.567	1.354	95.1	100.0
94	850	975	990	720	0	0	884	125.922	1.062	85.4	96.1
95	975	975	935	950	0	0	959	19.738	10.570	100.0	100.0
96	750	805	860	1105	0	0	880	156.578	0.830	77.7	86.5
97	835	950	860	845	0	0	873	52.678	2.325	100.0	100.0
98	690	795	720	800	0	0	751	54.829	0.023	50.8	0.0
99	755	760	790	850	0	0	789	43.661	0.888	79.6	89.2
100	870	900	930	920	0	0	905	26.458	5.858	100.0	100.0

APPENDIX J (Continued)
PAP TEST RESULTS - GREATER PITTSBURGH
INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 8

Airport: Greater Pittsburgh International Airport, Pittsburgh, PA
FAA Project Name: Midfield Terminal Project
Work Area Project Name: BP-02 N/S Taxiways and Tunnel

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
101	TW-D & F Sta 124+50	10/25/89	11/22/89	28
102		10/26/89	11/23/89	28
103		10/26/89	11/23/89	28
104	TW-A5 Sta 50+50 to 51+00	10/28/89	11/25/89	28
105	TW-A5 Sta 50+50 to 51+00	10/28/89	11/25/89	28
106	TW-A5 Sta 115+00 to 113+25	10/31/89	11/28/89	28
107	TW-A5 Sta 115+00 to 113+25	10/31/89	11/28/89	28
108	TW-N1 Sta 121+00 to 131+00	11/01/89	11/29/89	28
109	TW-N1 Sta 47+25 to 130+90	11/04/89	12/02/89	28
110	TW-N1 Sta 47+25 to 130+90	11/04/89	12/02/89	28
111	TW-D & F Sta 128+25 to 123+75	11/07/89	12/05/89	28
112	TW-D & F Sta 128+25 to 123+75	11/07/89	12/05/89	28
113	TW-A-N1 Sta 128+12 to 128+37	11/20/89	12/18/89	28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
101	850	800	800	870	0	0	830	35.590	2.248	100.0	100.0
102	870	860	840	770	0	0	835	45.092	1.885	100.0	100.0
103	810	790	830	820	0	0	813	17.078	3.660	100.0	100.0
104	820	770	750	820	0	0	790	35.590	1.124	87.5	98.0
105	760	750	790	790	0	0	773	20.616	1.091	86.4	97.0
106	785	790	810	965	0	0	838	85.684	1.021	84.0	94.7
107	845	1040	820	755	0	0	865	122.678	0.937	81.2	91.4
108	805	795	775	795	0	0	793	12.583	3.378	100.0	100.0
109	790	735	790	865	0	0	795	53.385	0.843	78.1	87.1
110	775	760	885	920	0	0	835	79.477	1.069	85.6	96.3
111	870	850	890	805	0	0	854	36.372	2.852	100.0	100.0
112	940	900	855	770	0	0	866	72.958	1.593	100.0	100.0
113	760	870	920	0	0	0	850	81.854	1.222	100.0	100.0

APPENDIX K
PAP TEST RESULTS - BY LOTS
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT DEFAULTS FOR AIRPORT PAVEMENT CONSTRUCTION
P-501, PORTLAND CEMENT CONCRETE PAVEMENT
for Norfolk International Airport

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1. THE LOWEST PWL IN PERCENT TO RECEIVE 100% PAYMENT: 90

2. THE LOWEST PWL IN PERCENT TO RECEIVE MINIMUM PAYMENT: 60
   THE MINIMUM PAY FACTOR IN PERCENT TO RECEIVE PAYMENT: 50

3. THE MIDPOINT SCALING FACTOR BETWEEN [1] AND [-1]: .6

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PAY FACTOR FORMULA IS: -3.212007 *PWL^2 + 6.484677 *PWL + -2.234484

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Press any key to return to program.
RESPONSE REQUEST MODE

APPENDIX K (Continued)
PAP TEST RESULTS - BY LOTS
NORFOLK INTERNATIONAL AIRPORT

FAA ACCEPTANCE AND PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENTS
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 1

Airport: Norfolk International Airport
Norfolk, VA
ORF

Consultant/Engineer: R. Kenneth Weeks, Engineers
Norfolk, VA

Construction Contractor: Williams Corp. of Va.
Norfolk, VA

Pavement Testing Laboratory: ATEL Associates of Va., Inc.
Norfolk, VA

FAA Contract Number: AIP #3-51-0036-06
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

Pavement Specification: P-501, PORTLAND CEMENT CONCRETE PAVEMENT
Design Target Specification in PSI: 700

Method of Testing: Flexural Strength Beams
ASTM Number: ASTM-C-78

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
1	Lane #1, north end at 0+80	11/24/87	12/22/87	28
2	Lane #1, north end	11/24/87	12/22/87	,28
3	Lane #3, north end at 0+80	11/25/87	12/23/87	28
4	Lane #3, north end at 0+330	11/25/87	12/23/87	28
5	Lane #5, north end	11/30/87	12/28/87	28
6	0+330 Ft	11/30/87	12/28/87	28
7	Lane #7, north end at 0+80	12/02/87	12/30/87	28
8	north end at 0+240	12/03/87	01/05/88	33
9	Lane #9, north end, 0+130 yards	12/07/87	01/05/88	29
10	Lane #9, north end 0+370	12/07/87	01/05/88	29

LOT NO.	-------TEST RESULT STRENGTH IN PSI-------- # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
1	655	660	705	710	0	0	683	29.011	-0.603	29.9	0.0
2	775	750	795	785	0	0	776	19.311	3.949	100.0	100.0
3	720	715	810	890	0	0	784	83.204	1.007	83.6	94.1
4	720	710	785	790	0	0	751	42.106	1.217	90.6	100.0
5	675	730	735	780	0	0	730	43.012	0.697	73.2	79.2
6	745	740	765	807	0	0	764	30.478	2.108	100.0	100.0
7	750	720	770	810	0	0	763	37.749	1.656	100.0	100.0
8	730	764	815	830	0	0	785	46.155	1.836	100.0	100.0
9	730	740	760	795	0	0	756	28.687	1.961	100.0	100.0
10	780	750	815	800	0	0	786	28.100	3.069	100.0	100.0

APPENDIX K (Continued)
PAP TEST RESULTS - BY LOTS
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 2

Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
11	3rd slab from west, 66' from north to south	12/08/87	01/05/88	28
12	3rd slab from west, 254' from north to south	12/08/87	01/05/88	28
13	Lane #11, North end 0+250 yds	12/10/87	01/07/88	28
14	Lane #11, north end, 0+410 ft	12/10/87	01/07/88	28
15	Lane #11, north end, 0+90	12/11/87	01/08/88	28
16	Lane #11	12/11/87	01/08/88	28
17	Lane #2, near runway, north end 0+100	12/12/87	12/26/87	14
18	Lane #2, north end 0+320	12/12/87	12/26/87	14
19	Lane #4, north end, 0+115 ft	12/14/87	12/28/87	14
20	Lane #4, north end 0+390 ft	12/14/87	12/28/87	14
21	Lane #6, north end 0+130 ft	12/16/87	01/13/88	28
22	Lane #6, 0+390	12/16/87	01/13/88	28
23	Lane #8, north end, 0+95 ft	12/17/87	01/14/88	28
24	Lane #8, 0+245 ft	12/18/87	01/15/88	28
25	Lane #8, 0+366 ft	12/18/87	01/15/88	28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
11	695	680	735	755	0	0	716	34.731	0.468	65.6	63.7
12	725	700	810	850	0	0	771	70.519	1.010	83.7	94.3
13	735	716	790	830	0	0	768	52.028	1.302	93.4	100.0
14	695	695	750	720	0	0	715	26.141	0.574	69.1	71.3
15	725	669	780	760	0	0	734	48.638	0.689	73.0	78.7
16	675	750	730	810	0	0	741	55.734	0.740	74.7	81.7
17	585	620	670	670	0	0	636	41.508	-1.536	0.0	0.0
18	660	640	720	725	0	0	686	42.696	-0.322	39.3	0.0
19	640	620	715	684	0	0	665	42.859	-0.822	22.6	0.0
20	675	655	745	700	0	0	694	38.810	-0.161	44.6	0.0
21	670	720	760	790	0	0	735	51.962	0.674	72.5	77.8
22	670	712	790	710	0	0	721	50.210	0.408	63.6	59.1
23	775	745	760	770	0	0	763	13.229	4.725	100.0	100.0
24	710	740	795	780	0	0	756	38.595	1.457	98.6	100.0
25	830	880	940	955	0	0	901	57.500	3.500	100.0	100.0

APPENDIX K (Continued)
PAP TEST RESULTS - BY LOTS
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 3

Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
26	Lane #8, north end 0+150 ft	12/21/87	01/18/88	28
27	Lane #10, north end, 3+35	01/04/88	02/01/88	28
28	Lane #10, from 0+00 to 0+50	01/13/88	02/10/88	28
29	Lane #12, north end 100+30 ft	01/19/88	02/16/88	28
30	Lane #12, north end, 3+10 ft	01/19/88	02/16/88	28
31	Lane #12, north end, 4+10 ft	01/21/88	02/04/88	14
32	Lane #14, east end, 1+10 ft	01/22/88	02/19/88	28
33	Area #2, center cross lane, seq. #2	02/01/88	02/29/88	28
34	Lane #2, area #3, east end, 0+85 ft	02/09/88	03/08/88	28
35	Lane #2, area #3, east end, 1+95 ft	02/09/88	03/08/88	28
36	Lane #4, south side, east end, 0+85 ft	02/10/88	03/09/88	28
37	Lane #4, area #3, south side, east end 1+98 ft	02/10/88	03/09/88	28
38	Area #2, lane #3, east end 0+95	02/15/88	03/14/88	28
39	Lane #3, area #2, east end, 1+15 ft	02/17/88	03/16/88	28
40	Area #2, Lane #4, East of 3=40'	02/17/88	03/16/88	28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
26	710	720	790	740	0	0	740	35.590	1.124	87.5	98.0
27	720	700	695	745	0	0	715	22.730	0.660	72.0	76.9
28	720	770	830	810	0	0	783	48.563	1.699	100.0	100.0
29	759	750	825	790	0	0	781	33.971	2.384	100.0	100.0
30	662	638	720	740	0	0	690	47.917	-0.209	43.0	0.0
31	600	640	760	760	0	0	690	82.462	-0.121	46.0	0.0
32	750	670	745	770	0	0	734	43.851	0.770	75.7	83.3
33	670	690	810	880	0	0	763	99.791	0.626	70.9	74.8
34	875	790	860	880	0	0	851	41.708	3.626	100.0	100.0
35	720	730	810	810	0	0	768	49.244	1.371	95.7	100.0
36	700	685	760	785	0	0	733	47.697	0.681	72.7	78.2
37	710	710	780	770	0	0	743	37.749	1.126	87.5	98.1
38	700	730	825	805	0	0	765	59.582	1.091	86.4	97.0
39	770	760	830	800	0	0	790	31.623	2.846	100.0	100.0
40	720	760	780	850	0	0	778	54.391	1.425	97.5	100.0

APPENDIX K (Continued)
PAP TEST RESULTS - BY LOTS
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 4

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Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
41	Lane #1, area #2, east end, 0+88 ft	02/18/88	03/17/88	28
42	Lane #1, area #2, east end, 2+90 ft	02/18/88	03/17/88	28
43	Area #3, Lane #1, East end 0+65'	02/22/88	03/21/88	28
44	Lane #1, area #3, 1+95 ft	02/22/88	03/21/88	28
45	Lane #3, area #7, east end, 0+40	02/23/88	03/22/88	28
46	Lane #3, area #3, 1+95 ft	02/23/88	03/22/88	28
48	Area #3, lane #6, east end 0+93 ft	03/02/88	03/30/88	28
49	Lane #6, area #3, east end, 1+98 ft	03/02/88	03/30/88	28
50	Lane #8, area #3, east end, 0+78 ft	03/03/88	03/31/88	28
51	Lane #8, area #3, east end, 1+95 ft	03/03/88	03/31/88	28
52	Lane #10, area #3, 0+70 ft	03/07/88	04/04/88	28
53	Lane #10, area #3, 1+98 ft	03/07/88	04/04/88	28
54	Lane #12, area #3, east end, 0+18 ft	03/08/88	04/05/88	28
55	Lane #12, area #3, 0+52 ft	03/08/88	04/05/88	28
56	Lane #5, area #3, 0+60 ft	03/09/88	04/06/88	28

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LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
41	720	720	830	800	0	0	768	56.199	1.201	90.0	100.0
42	610	675	695	710	0	0	673	44.064	-0.624	29.2	0.0
43	770	850	880	865	0	0	841	49.054	2.880	100.0	100.0
44	700	650	780	770	0	0	725	61.373	0.407	63.6	59.0
45	680	705	760	810	0	0	739	58.077	0.667	72.2	77.4
46	630	640	730	720	0	0	680	52.281	-0.383	37.2	0.0
48	870	810	890	920	0	0	873	46.458	3.713	100.0	100.0
49	740	760	800	800	0	0	775	30.000	2.500	100.0	100.0
50	850	835	870	900	0	0	864	28.100	5.828	100.0	100.0
51	710	725	800	815	0	0	763	52.678	1.186	89.5	99.7
52	820	755	855	860	0	0	823	48.391	2.531	100.0	100.0
53	630	650	760	705	0	0	686	58.506	-0.235	42.2	0.0
54	720	700	860	835	0	0	779	80.454	0.979	82.6	93.1
55	760	730	860	890	0	0	810	77.028	1.428	97.6	100.0
56	670	720	905	820	0	0	779	104.752	0.752	75.1	82.3

APPENDIX K (Continued)
PAP TEST RESULTS - BY LOTS
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 5

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Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
57	Lane #5, area #3, 1+80 ft	03/09/88	04/06/88	28
58	Area #3, Lane #7, 0+90'	03/11/88	04/08/88	28
59	Lane #7, area #7, east end, 1+95	03/11/88	04/08/88	28
60	Lane #9, area #3, east end,0+96 ft	03/23/88	04/20/88	28
61	Lane #9, area #3, east end, 1+95	03/23/88	04/20/88	28
62	Lane #11, area #3, east end, 0+58	03/24/88	04/21/88	28
63	Lane #11, area #3, east end, 1+42 ft	03/24/88	04/21/88	28
64	Area #4, Lane #15, North end, 0+75'	03/30/88	04/27/88	28
65	Lane #15, area #4, north end, 3+90 ft	03/30/88	04/27/88	28
66	Lane #16, area #4, north end, 0+70 ft	04/05/88	05/03/88	28
67	Lane #16, area #4, north end, 4+40 ft	04/05/88	05/03/88	28
68	Lane #14, area #4, from 10 ft side, 3+66 ft	04/05/88	05/03/88	28
69	Area #4, lane #14, north end, 2+68 ft	04/06/88	05/04/88	28
70	Lane #14, area #4, north end 5+95 ft	04/06/88	05/04/88	28
73	Lane #3, northeast area, at northeast 1/3	09/20/88	10/18/88	28

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LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
57	800	730	840	800	0	0	793	45.735	2.023	100.0	100.0
58	710	710	820	910	0	0	788	96.738	0.905	80.2	90.0
59	700	690	780	800	0	0	743	55.603	0.764	75.5	83.0
60	670	700	820	840	0	0	758	85.000	0.676	72.5	77.9
61	630	715	850	810	0	0	751	98.689	0.519	67.3	67.5
62	720	670	780	740	0	0	728	45.735	0.601	70.0	73.2
63	710	620	730	740	0	0	700	54.772	0.000	50.0	0.0
64	600	680	776	798	0	0	714	91.380	0.148	54.9	0.0
65	730	730	761	714	0	0	734	19.670	1.716	100.0	100.0
66	730	730	800	830	0	0	773	50.580	1.433	97.8	100.0
67	670	660	800	800	0	0	733	78.049	0.416	63.9	59.7
68	820	730	840	780	0	0	793	48.563	1.905	100.0	100.0
69	660	630	730	725	0	0	686	49.223	-0.279	40.7	0.0
70	670	650	760	720	0	0	700	49.666	0.000	50.0	0.0
73	660	600	720	750	0	0	683	66.521	-0.263	41.2	0.0

APPENDIX K (Continued)
PAP TEST RESULTS - BY LOTS
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 6

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Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
74	Lane #3 southeast, 30 ft from end	09/20/88	10/18/88	28
75	Lane #5, 6+30 on east end	09/21/88	10/19/88	28
76	Lane #5, 4+80 on west end	09/21/88	10/19/88	28
77	Lane #7, 780 to 690	10/03/88	10/31/88	28
78	Lane #7	10/05/88	11/02/88	28
79	Lane #7	10/05/88	11/02/88	28
80	Lane #9	10/05/88	11/02/88	28
81	Lane #9	10/06/88	11/03/88	28
82	Lane #11, west end	10/07/88	11/04/88	28
83	Lane #11, east end	10/07/88	11/04/88	28
84	Lane #2, east end	10/08/88	11/05/88	28
85	Lane #2, west end	10/08/88	11/05/88	28
86	Lane #4, east end	10/10/88	11/07/88	28
87	Lane #4, west end	10/10/88	11/07/88	28
88	Lane #8, at 65 ft	10/12/88	11/09/88	28

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LOT NO.	-------TEST RESULT STRENGTH IN PSI-------- # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
74	660	610	780	775	0	0	706	84.791	0.074	52.5	0.0
75	670	690	710	840	0	0	728	76.757	0.358	61.9	55.0
76	730	630	860	870	0	0	773	114.419	0.634	71.1	75.3
77	600	620	860	830	0	0	728	136.473	0.202	56.7	0.0
78	640	710	730	0	0	0	693	47.258	-0.141	46.1	0.0
79	550	730	790	0	0	0	690	124.900	-0.080	47.8	0.0
80	660	860	930	0	0	0	817	140.119	0.833	75.6	83.3
81	620	665	750	780	0	0	704	74.092	0.051	51.7	0.0
82	605	540	830	820	0	0	699	148.233	-0.008	49.7	0.0
83	605	620	700	790	0	0	679	85.086	-0.250	41.7	0.0
84	600	685	901	910	0	0	774	155.801	0.475	65.8	64.2
85	700	770	715	740	0	0	731	30.653	1.019	84.0	94.6
86	680	640	875	735	0	0	733	102.673	0.317	60.6	51.4
87	610	820	800	0	0	0	743	115.902	0.374	60.5	51.3
88	620	580	840	920	0	0	740	165.731	0.241	58.0	0.0

APPENDIX K (Continued)
PAP TEST RESULTS - BY LOTS
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 7

Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Apron Expansion, 1988

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
89	Lane #8, west end	10/12/88	11/09/88	28
90	Lane #6, east end	10/13/88	11/10/88	28
91	Lane #6, west end	10/13/88	11/10/88	28
92	Lane #8, east end	10/14/88	11/11/88	28
93	Lane #8, west end	10/14/88	11/11/88	28
94	Lane #10, west end	10/15/88	11/12/88	28
95	Lane #10, east end	10/15/88	11/12/88	28
96	Lane #12, east end	10/17/88	11/14/88	28
97	Lane #12, west end	10/17/88	11/14/88	28
98	Lane #2, north end, 0-25	10/18/88	11/15/88	28
99	Lane #2, south end, 0-25	10/18/88	11/15/88	28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
89	530	580	890	830	0	0	708	178.955	0.042	51.4	0.0
90	620	710	980	850	0	0	790	158.114	0.569	69.0	71.0
91	600	690	800	840	0	0	733	108.743	0.299	60.0	0.0
92	635	610	880	810	0	0	734	131.996	0.256	58.5	0.0
93	610	615	760	860	0	0	711	121.132	0.093	53.1	0.0
94	595	610	910	810	0	0	731	154.293	0.203	56.8	0.0
95	745	670	800	820	0	0	759	67.129	0.875	79.2	88.6
96	575	575	750	790	0	0	673	113.761	-0.242	41.9	0.0
97	600	630	750	780	0	0	690	88.318	-0.113	46.2	0.0
98	505	505	830	920	0	0	690	216.756	-0.046	48.5	0.0
99	525	510	825	855	0	0	679	186.698	-0.114	46.2	0.0

APPENDIX L
PAP TEST RESULTS - 28 DAYS ONLY
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT DEFAULTS FOR AIRPORT PAVEMENT CONSTRUCTION
P-501, PORTLAND CEMENT CONCRETE PAVEMENT
for Norfolk International Airport

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1. THE LOWEST PWL IN PERCENT TO RECEIVE 100% PAYMENT: 90

2. THE LOWEST PWL IN PERCENT TO RECEIVE MINIMUM PAYMENT: 60
   THE MINIMUM PAY FACTOR IN PERCENT TO RECEIVE PAYMENT: 50

3. THE MIDPOINT SCALING FACTOR BETWEEN [1] AND [-1]: .6

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PAY FACTOR FORMULA IS: -3.212007 *PWL^2 + 6.484677 *PWL + -2.234484

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Press any key to return to program.
RESPONSE REQUEST MODE

APPENDIX L (Continued)
PAP TEST RESULTS - 28 DAYS ONLY
NORFOLK INTERNATIONAL AIRPORT

FAA ACCEPTANCE AND PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENTS
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 1

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Airport: Norfolk International Airport
Norfolk, VA
ORF

Consultant/Engineer: R. Kenneth Weeks, Engineers
Norfolk, VA

Construction Contractor: Williams Corp. of Va.
Norfolk, VA

Pavement Testing Laboratory: ATEL Associates of Va., Inc.
Norfolk, VA

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FAA Contract Number: AIP #3-51-0036-06
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Only 28-day tests

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Pavement Specification: P-501, PORTLAND CEMENT CONCRETE PAVEMENT
Design Target Specification in PSI: 700

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Method of Testing: Flexural Strength Beams
ASTM Number: ASTM-C-78

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
1	Lot 1 & 2	11/24/87	12/22/87	28
2	Lot 3 & 4	11/25/87	12/23/87	28
3	Lot 5 & 6	11/30/87	12/28/87	28
4	Lot 7 & 8	12/02/87	12/30/87	28
5	Lot 9 & 10	12/07/87	01/05/88	29
6	Lots 11 & 12	12/08/87	01/05/88	28
7	Lots 13 & 14	12/10/87	01/07/88	28
8	Lots 15 & 16	12/11/87	01/08/88	28
11	Lots 21 & 22	12/16/87	01/13/88	28
12	Lot 23	12/17/87	01/14/88	28

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LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
1	705	710	795	785	0	0	749	47.850	1.019	84.0	94.6
2	810	890	785	790	0	0	819	48.713	2.438	100.0	100.0
3	735	780	765	807	0	0	772	30.037	2.389	100.0	100.0
4	770	810	815	830	0	0	806	25.617	4.148	100.0	100.0
5	760	795	815	800	0	0	793	23.274	3.974	100.0	100.0
6	735	755	810	850	0	0	788	52.361	1.671	100.0	100.0
7	790	830	750	720	0	0	773	47.871	1.514	100.0	100.0
8	780	760	730	810	0	0	770	33.665	2.079	100.0	100.0
11	760	790	790	710	0	0	763	37.749	1.656	100.0	100.0
12	775	760	770	0	0	0	768	7.642	8.941	100.0	100.0

APPENDIX L (Continued)
PAP TEST RESULTS - 28 DAYS ONLY
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 2

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. port: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Only 28-day tests

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
13	Lots 24 & 25	12/18/87	01/15/88	28
15	Lots 26, 27 & 28	01/04/88	02/01/88	28
17	Lots 29 & 30	01/19/88	02/16/88	28
18	Lots 32 & 33	01/22/88	02/19/88	28
19	Lots 34 & 35	02/09/88	03/08/88	28
20	Lots 36 & 37	02/10/88	03/09/88	28
21	Lots 38, 39 & 40	02/17/88	03/16/88	28
22	Lots 41 & 42	02/18/88	03/17/88	28
23	Lots 43 & 44	02/22/88	03/21/88	28
24	Lots 45 & 46	02/23/88	03/22/88	28
25	Lots 48 & 49	03/02/88	03/30/88	28
26	Lots 50 & 51	03/03/88	03/31/88	28
27	Lots 52 & 53	03/07/88	04/04/88	28
28	Lots 54 & 55	03/08/88	04/05/88	28
29	Lots 56 & 57	03/09/88	04/06/88	28

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LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
13	795	780	940	955	0	0	868	92.781	1.805	100.0	100.0
15	790	740	695	745	830	810	768	50.465	1.354	92.5	100.0
17	825	790	720	740	0	0	769	47.675	1.442	98.1	100.0
18	745	770	810	880	0	0	801	58.931	1.718	100.0	100.0
19	860	880	810	810	0	0	840	35.590	3.934	100.0	100.0
20	760	785	780	770	0	0	774	11.087	6.652	100.0	100.0
21	825	805	830	800	780	850	815	24.900	4.619	100.0	100.0
22	830	800	695	710	0	0	759	66.380	0.885	79.5	89.1
23	880	865	780	770	0	0	824	56.771	2.180	100.0	100.0
24	760	810	730	720	0	0	755	40.415	1.361	95.4	100.0
25	890	920	800	800	0	0	853	61.847	2.466	100.0	100.0
26	870	900	800	815	0	0	846	46.793	3.125	100.0	100.0
27	855	860	760	705	0	0	795	75.609	1.256	91.9	100.0
28	860	835	860	890	0	0	861	22.500	7.167	100.0	100.0
29	905	820	840	800	0	0	841	45.529	3.102	100.0	100.0

APPENDIX L (Continued)
PAP TEST RESULTS - 28 DAYS ONLY
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 3

Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Only 28-day tests

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
30	Lots 58 & 59	03/11/88	04/08/88	28
31	Lots 60 & 61	03/23/88	04/20/88	28
32	Lots 62 & 63	03/24/88	04/21/88	28
33	Lots 64 & 65	03/30/88	04/27/88	28
34	Lots 66, 67 and 68	04/05/88	05/03/88	28
35	Lots 69 & 70	04/06/88	05/04/88	28
37	Lots 73 & 74	09/20/88	10/18/88	28
38	Lots 75 & 76	09/21/88	10/19/88	28
39	Lots 77 & 81	10/03/88	10/31/88	28
40	Lots 78, 79 & 80	10/05/88	11/02/88	28
41	Lots 82 & 83	10/07/88	11/04/88	28
42	Lots 84 & 85	10/08/88	11/05/88	28
43	Lots 86 & 87	10/10/88	11/07/88	28
44	Lots 88 & 89	10/12/88	11/09/88	28
45	Lots 90 & 91	10/14/88	11/11/88	28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
30	820	910	780	800	0	0	828	57.373	2.222	100.0	100.0
31	820	840	850	810	0	0	830	18.257	7.120	100.0	100.0
32	780	740	730	740	0	0	748	22.174	2.142	100.0	100.0
33	776	798	761	714	0	0	762	35.575	1.750	100.0	100.0
34	800	830	800	800	840	780	808	22.287	4.861	100.0	100.0
35	730	725	760	720	0	0	734	17.970	1.878	100.0	100.0
37	720	750	780	775	0	0	756	27.500	2.045	100.0	100.0
38	710	840	860	870	0	0	820	74.386	1.613	100.0	100.0
39	860	830	750	780	0	0	805	49.329	2.129	100.0	100.0
40	710	730	730	790	860	930	792	87.273	1.050	85.2	95.9
41	830	820	700	790	0	0	785	59.161	1.437	97.9	100.0
42	901	910	715	740	0	0	817	103.339	1.127	87.6	98.1
43	875	735	820	800	0	0	808	57.807	1.860	100.0	100.0
44	840	9[illegible]0	890	830	0	0	870	42.426	4.007	100.0	100.0
45	980	850	800	840	0	0	868	78.049	2.146	100.0	100.0

APPENDIX L (Continued)
PAP TEST RESULTS - 28 DAYS ONLY
NORFOLK INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, PORTLAND CEMENT CONCRETE PAVEMENT

06-08-1990 PAGE 4

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Airport: Norfolk International Airport, Norfolk, VA
FAA Project Name: Terminal Apron Expansion
Work Area Project Name: Only 28-day tests

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
46	Lots 92 & 93	10/14/88	11/11/88	28
47	Lots 94 & 95	10/15/88	11/12/88	28
48	Lots 96 & 97	10/17/88	11/14/88	28
49	Lots 98 & 99	10/18/88	11/15/88	28

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LOT NO.	-------TEST # 1	RESULT # 2	STRENGTH # 3	IN # 4	PSI # 5	-------- # 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
46	880	810	760	860	0	0	828	53.774	2.371	100.0	100.0
47	910	810	800	820	0	0	835	50.662	2.665	100.0	100.0
48	750	790	750	780	0	0	768	20.616	3.274	100.0	100.0
49	830	920	825	855	0	0	858	43.684	3.605	100.0	100.0

APPENDIX M
PAP TEST RESULTS - BY LOTS
DULLES INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT DEFAULTS FOR AIRPORT PAVEMENT CONSTRUCTION.
P-501, Portland Cement Concrete Pavement
for Dulles International Airport

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1. THE LOWEST PWL IN PERCENT TO RECEIVE 100% PAYMENT: 90

2. THE LOWEST PWL IN PERCENT TO RECEIVE MINIMUM PAYMENT: 60
   THE MINIMUM PAY FACTOR IN PERCENT TO RECEIVE PAYMENT: 50

3. THE MIDPOINT SCALING FACTOR BETWEEN [1] AND [-1]: .6

****

PAY FACTOR FORMULA IS: -3.212007 *PWL^2 + 6.484677 *PWL + -2.234484

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Press any key to return to program.
RESPONSE REQUEST MODE

APPENDIX M (Continued)
PAP TEST RESULTS - BY LOTS
DULLES INTERNATIONAL AIRPORT

FAA ACCEPTANCE AND PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENTS
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 1

Airport: Dulles International Airport
Washington DC
IAD

Consultant/Engineer:

Construction Contractor:

Pavement Testing Laboratory: ATEC Assoc. of Virginia, Inc.
Chantilly, VA 22021

FAA Contract Number:
FAA Project Name: Concrete Pavement Panel
Work Area Project Name: Runway No. 30 - By lots

Pavement Specification: P-501, Portland Cement Concrete Pavement
Design Target Specification in PSI: 650

Method of Testing:
ASTM Number:

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
1	North Lane, Station 31+47 to 31+54	06/30/88	07/07/88	7
2	North Lane, Station 45+70 to 45+80	07/01/88	07/08/88	7
3	Station 50+60 to 50+70	07/01/88	07/08/88	7
4	North Lane, Station 32+80	07/06/88	07/20/88	14
5	North Lane, Station 34+20	07/06/88	07/20/88	14
6	North Lane, Station 35+40	07/06/88	07/20/88	14
7	North Lane. Station 36+60	07/06/88	08/03/88	28
8	North Lane, Station 37+80	07/06/88	07/20/88	14
9	North Lane, Station 39+20	07/06/88	07/20/88	14
10	North Lane, Station 40+40	07/06/88	07/20/88	14

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
1	530	570	840	870	0	0	703	177.271	0.296	59.9	0.0
2	550	590	860	850	0	0	713	165.404	0.378	62.6	56.6
3	645	590	760	770	0	0	691	88.164	0.468	65.6	63.7
4	550	570	735	740	0	0	649	102.825	-0.012	49.6	0.0
5	595	610	710	740	0	0	664	72.039	0.191	56.4	0.0
6	570	550	675	690	0	0	621	71.458	-0.402	36.6	0.0
7	610	670	715	705	0	0	675	47.434	0.527	67.6	68.1
8	635	605	720	730	0	0	673	61.981	0.363	62.1	55.4
9	560	560	750	750	0	0	655	109.697	0.046	51.5	0.0
10	720	670	695	690	0	0	694	20.565	2.127	100.0	100.0

APPENDIX M (Continued)
PAP TEST RESULTS - BY LOTS
DULLES INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 2

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Airport: Dulles International Airport, Washington DC
FAA Project Name: Concrete Pavement Panel
Work Area Project Name: Runway No. 30 - By lots

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
11	North Lane, Station 41+60	07/06/88	07/20/88	14
12	North Lane, Station 42+80	07/06/88	07/20/88	14
13	North Lane, Station 44+00	07/06/88	08/03/88	28
14	South Lane, Station 50+40	07/07/88	07/21/88	14
15	Station 30+00, 63 ft right	07/08/88	07/22/88	14
16	W2, Station 21+90	07/11/88	07/25/88	14
17	W2, Station 12,28, 38 ft right	07/11/88	07/25/88	14
18	South Lane, Station 43+60	07/13/88	08/10/88	28
19	South Lane, Station 43+00	07/13/88	07/27/88	14
20	South Lane, Station 41+80	07/13/88	07/27/88	14
21	South Lane, Station 40+60	07/13/88	07/27/88	14
22	South Lane, Station 39+40	07/13/88	07/27/88	14
23	South Lane, Station 38+20	07/13/88	08/10/88	28
24	South Lane, Station 36+60	07/13/88	07/27/88	14
25	South Lane, Station 35+40	07/13/88	07/27/88	14

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LOT NO.	-------TEST RESULT STRENGTH IN PSI-------- # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
11	610	655	755	805	0	0	706	89.478	0.629	71.0	75.0
12	755	745	745	805	0	0	763	28.723	3.917	100.0	100.0
13	715	660	690	690	0	0	689	22.500	1.722	100.0	100.0
14	700	710	710	740	0	0	715	17.321	3.753	100.0	100.0
15	695	680	700	720	0	0	699	16.520	2.951	100.0	100.0
16	555	695	695	640	0	0	646	66.128	-0.057	48.1	0.0
17	725	650	680	740	0	0	699	41.307	1.180	89.3	99.5
18	685	745	715	735	0	0	720	26.458	2.646	100.0	100.0
19	685	650	790	745	0	0	718	62.250	1.084	86.1	96.8
20	805	665	700	795	0	0	741	69.447	1.314	93.8	100.0
21	665	635	705	685	0	0	673	29.861	0.753	75.1	82.4
22	665	715	700	750	0	0	708	35.237	1.632	100.0	100.0
23	645	680	700	665	0	0	673	23.274	0.967	82.2	92.6
24	640	640	690	665	0	0	659	23.936	0.366	62.2	55.6
25	700	700	730	770	0	0	725	33.166	2.261	100.0	100.0

APPENDIX M (Continued)
PAP TEST RESULTS - BY LOTS
DULLES INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 3

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Airport: Dulles International Airport, Washington DC
FAA Project Name: Concrete Pavement Panel
Work Area Project Name: Runway No. 30 - By lots

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LOT NO.	SAMPLE LOCATION		SAMPLE DATE	TEST DATE	AGE OF SAMPLE
26	South Lane,	Station 34+20	07/13/88	07/27/88	14
27	South Lane,	Station 33+60	07/14/88	07/28/88	14
28	W2,	Station 18+43	07/14/88	07/28/88	14
29	W2,	Station 38+63 left	08/19/88	09/02/88	14
30	W2,	Station 37+88 left	08/19/88	09/02/88	14
31	W2,	Station 32+70, Centerline	08/22/88	09/05/88	14
32	W2,	Station 34+90, Centerline	08/22/88	09/05/88	14
33	W2,	Station 35+70, Right	08/22/88	09/05/88	14
34	W2,	Station 39+63 Left	08/23/88	09/06/88	14
35	W2,	Station 40+63 Right	08/23/88	09/06/88	14
36	W2,	Station 45+13 Right	08/23/88	09/06/88	14
37	W2,	Station 47+13 Left	08/23/88	09/20/88	28
38	W2,	Station 46+38 Left	08/23/88	09/06/88	14
39	T2,	Station 9+25 Centerline	08/27/88	09/10/88	14
40	W2,	Station 47+38 Centerline	08/31/88	09/14/88	14

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LOT NO.	-------TEST RESULT STRENGTH IN PSI-------- # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
26	715	635	690	700	0	0	685	34.881	1.003	83.4	94.0
27	680	690	690	765	0	0	706	39.449	1.426	97.5	100.0
28	750	680	665	730	0	0	706	40.285	1.396	96.5	100.0
29	835	895	830	815	0	0	844	35.208	5.503	100.0	100.0
30	755	725	760	760	0	0	750	16.833	5.941	100.0	100.0
31	855	815	930	935	0	0	884	58.648	3.986	100.0	100.0
32	715	745	790	840	0	0	773	54.544	2.246	100.0	100.0
33	710	665	920	900	0	0	799	130.024	1.144	88.1	98.6
34	660	685	730	790	0	0	716	57.064	1.161	88.7	99.0
35	750	846	855	980	0	0	858	94.341	2.202	100.0	100.0
36	765	815	830	825	0	0	809	29.826	5.323	100.0	100.0
37	830	815	840	840	0	0	831	11.815	15.340	100.0	100.0
38	750	670	790	725	0	0	734	50.229	1.667	100.0	100.0
39	835	785	1120	1150	0	0	973	189.143	1.705	100.0	100.0
40	705	780	730	860	0	0	769	68.359	1.737	100.0	100.0

APPENDIX M (Continued)
PAP TEST RESULTS - BY LOTS
DULLES INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 4

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Airport: Dulles International Airport, Washington DC
FAA Project Name: Concrete Pavement Panel
Work Area Project Name: Runway No. 30 - By lots

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LOT NO.	SAMPLE LOCATION		SAMPLE DATE	TEST DATE	AGE OF SAMPLE
41	W2,	Station 42+63, 25 ft Left	08/31/88	09/14/88	14
42	W2,	Station 44+63, 25 ft Left	09/01/88	09/15/88	14
43	W2,	Station 43+13, 25 ft Left	09/01/88	09/15/88	14
44	W2,	Station 39+88, 25 ft Left	09/01/88	09/15/88	14
45	W2,		09/01/88	09/15/88	14
46	W2,	Station 48+88, 25 ft Left	09/02/88	09/16/88	14
47	R1,	Station 47+75, Centerline	09/02/88	09/16/88	14
48	R2,	Station 48+25, Centerline	09/02/88	09/16/88	14
49	R2,	Station 1+00, Centerline	09/14/88	09/28/88	14
50	R2,	Station 1+75 Centerline	09/14/88	09/28/88	14
51	R1,	Station 47+75 Centerline	10/01/88	10/15/88	14

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LOT NO.	-------TEST RESULT STRENGTH IN PSI-------- # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
41	820	750	890	800	0	0	815	58.023	2.844	100.0	100.0
42	620	690	700	705	0	0	679	39.660	0.725	74.2	80.8
43	725	660	700	760	0	0	711	42.106	1.455	98.5	100.0
44	920	880	820	865	0	0	871	41.307	5.356	100.0	100.0
45	760	905	805	805	0	0	819	61.288	2.753	100.0	100.0
46	645	645	790	705	0	0	696	68.602	0.674	72.5	77.8
47	755	710	1090	1070	0	0	906	201.634	1.271	92.4	100.0
48	810	810	920	1000	0	0	885	92.556	2.539	100.0	100.0
49	890	930	1210	1110	0	0	1035	150.886	2.552	100.0	100.0
50	680	900	1160	1300	0	0	1010	275.439	1.307	93.6	100.0
51	845	885	1085	1050	0	0	966	118.910	2.660	100.0	100.0

APPENDIX N
PAP TEST RESULTS - 28 DAYS ONLY
DULLES INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT DEFAULTS FOR AIRPORT PAVEMENT CONSTRUCTION
P-501, Portland Cement Concrete Pavement
for Dulles International Airport

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  1.  THE LOWEST PWL IN PERCENT TO RECEIVE 100% PAYMENT:  90

  2.  THE LOWEST PWL IN PERCENT TO RECEIVE MINIMUM PAYMENT:  60
      THE MINIMUM PAY FACTOR IN PERCENT TO RECEIVE PAYMENT:  50

  3.  THE MIDPOINT SCALING FACTOR BETWEEN [1] AND [-1]:  .6

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 PAY FACTOR FORMULA IS: -3.212007 *PWL^2 +  6.484677 *PWL + -2.234484

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Press any key to return to program.
RESPONSE REQUEST MODE

APPENDIX N (Continued)
PAP TEST RESULTS - 28 DAYS ONLY
DULLES INTERNATIONAL AIRPORT

FAA ACCEPTANCE AND PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENTS
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 1

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Airport: Dulles International Airport
Washington DC
IAD

Consultant/Engineer:

Construction Contractor:

Pavement Testing Laboratory: ATEC Assoc. of Virginia, Inc.
Chantilly, VA 22021

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FAA Contract Number:
FAA Project Name: Concrete Pavement Panel
Work Area Project Name: Best of two lots for Runway No. 30

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Pavement Specification: P-501, Portland Cement Concrete Pavement
Design Target Specification in PSI: 650

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Method of Testing:
ASTM Number:

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LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
1	Lots 1 & 2			
2	Lots 3 & 4			
3	Lots 5 & 6			
4	Lots 7 & 8			
5	Lots 9 & 10			
6	Lots 11 & 12			
7	Lots 13 & 14			
8	Lots 15 & 16			
9	Lots 17 & 18			
10	Lots 19 & 20			

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LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
1	840	870	860	850	0	0	855	12.910	15.870	100.0	100.0
2	760	770	735	740	0	0	751	16.520	6.129	100.0	100.0
3	710	740	675	690	0	0	704	28.100	1.913	100.0	100.0
4	715	705	720	730	0	0	718	10.408	6.485	100.0	100.0
5	750	750	720	695	0	0	729	26.575	2.963	100.0	100.0
6	755	805	755	805	0	0	780	28.868	4.503	100.0	100.0
7	715	690	710	740	0	0	714	20.565	3.100	100.0	100.0
8	700	720	695	695	0	0	703	11.902	4.411	100.0	100.0
9	725	740	745	735	0	0	736	8.539	10.100	100.0	100.0
10	790	745	805	795	0	0	784	26.575	5.033	100.0	100.0

APPENDIX N (Continued)
PAP TEST RESULTS - 28 DAYS ONLY
DULLES INTERNATIONAL AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-07-1990 PAGE 2

Airport: Dulles International Airport, Washington DC
FAA Project Name: Concrete Pavement Panel
Work Area Project Name: Best of two lots for Runway No. 30

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
11	Lots 21 & 22			
12	Lots 23 & 24			
13	Lots 25 & 26			
14	Lots 27 & 28			
15	Lots 29 & 30			
16	Lots 31 & 32			
17	Lots 33 & 34			
18	Lots 35 & 36			
19	Lots 37 & 38			
20	Lots 39 & 40			
21	Lots 41 & 42			
22	Lots 43 & 44			
23	Lots 45 & 46			
24	Lots 47 & 48			
25	Lots 49, 50, and 51			

LOT NO.	-------TEST RESULT STRENGTH IN PSI-------- # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
11	705	685	715	750	0	0	714	27.195	2.344	100.0	100.0
12	680	700	690	665	0	0	684	14.930	2.260	100.0	100.0
13	730	770	715	700	0	0	729	30.104	2.616	100.0	100.0
14	690	765	750	730	0	0	734	32.500	2.577	100.0	100.0
15	835	895	755	760	0	0	811	66.755	2.416	100.0	100.0
16	930	935	790	840	0	0	874	70.873	3.157	100.0	100.0
17	920	900	730	790	0	0	835	90.370	2.047	100.0	100.0
18	855	980	830	825	0	0	873	72.858	3.054	100.0	100.0
19	840	840	750	790	0	0	805	43.589	3.556	100.0	100.0
20	1120	1150	780	860	0	0	978	185.180	1.769	100.0	100.0
21	820	890	700	705	0	0	779	92.590	1.391	96.4	100.0
22	725	760	920	880	0	0	821	93.486	1.832	100.0	100.0
23	905	805	790	705	0	0	801	81.993	1.845	100.0	100.0
24	1090	1070	920	1000	0	0	1020	77.028	4.803	100.0	100.0
25	1210	1110	1160	1300	1085	1050	1153	91.638	5.484	100.0	100.0

APPENDIX O
PAP TEST RESULTS
BALTIMORE/WASHINGTON INTERNATIONAL

FAA PAYMENT ADJUSTMENT DEFAULTS FOR AIRPORT PAVEMENT CONSTRUCTION
P-501, Portland Cement Concrete Pavement
for Baltimore/Washington International

****

1. THE LOWEST PWL IN PERCENT TO RECEIVE 100% PAYMENT: 90

2. THE LOWEST PWL IN PERCENT TO RECEIVE MINIMUM PAYMENT: 60
   THE MINIMUM PAY FACTOR IN PERCENT TO RECEIVE PAYMENT: 50

3. THE MIDPOINT SCALING FACTOR BETWEEN [1] AND [-1]: .6

****

PAY FACTOR FORMULA IS: -3.212007 *PWL^2 + 6.484677 *PWL + -2.234484

****

Press any key to return to program.
RESPONSE REQUEST MODE

APPENDIX O (Continued)
PAP TEST RESULTS
BALTIMORE/WASHINGTON INTERNATIONAL

FAA ACCEPTANCE AND PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENTS
P-501, Portland Cement Concrete Pavement

06-08-1990 PAGE 1

****

Airport: Baltimore/Washington International
Baltimore, MD
BWI

Consultant/Engineer:

Construction Contractor: P. Flanigan & Sons, Inc.
Baltimore, MD

Pavement Testing Laboratory: Penniman & Browne, Inc.
Baltimore, MD

****

FAA Contract Number: SAA-CO-87-010
FAA Project Name: 1987 Expansion
Work Area Project Name: Pier D/Y Headstand

****

Pavement Specification: P-501, Portland Cement Concrete Pavement
Design Target Specification in PSI: 700

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Method of Testing:
ASTM Number:

****

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
1	8/21/87 & 8/22/87	08/21/87		
2		08/24/87		
3		08/26/87		
4		08/28/87		
5		09/29/87		
6		10/01/87		
7		10/02/87		
8		10/02/87		
9		10/06/87		
10		10/07/87		

****

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
1	763	844	860	901	826	0	839	50.633	2.741	100.0	100.0
2	863	903	930	991	0	0	922	53.749	4.126	100.0	100.0
3	745	784	827	856	0	0	803	48.683	2.116	100.0	100.0
4	802	879	906	0	0	0	862	53.966	3.008	100.0	100.0
5	888	845	732	822	0	0	822	65.789	1.851	100.0	100.0
6	898	1071	990	938	0	0	974	74.692	3.672	100.0	100.0
7	996	836	865	872	0	0	892	70.901	2.712	100.0	100.0
8	901	845	839	840	0	0	856	29.949	5.217	100.0	100.0
9	977	981	1112	880	0	0	988	95.235	3.019	100.0	100.0
10	1025	1096	1008	1017	0	0	1037	40.270	8.356	100.0	100.0

APPENDIX O (Continued)
PAP TEST RESULTS
BALTIMORE/WASHINGTON INTERNATIONAL

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-08-1990 PAGE 2

Airport: Baltimore/Washington International, Baltimore, MD
FAA Project Name: 1987 Expansion
Work Area Project Name: Pier D/Y Headstand

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
11	10/08/87 & 10/09/87	10/08/87		
12		10/12/87		
13		10/13/87		
14		10/14/87		
15		10/26/87		
16		10/27/87		
17	10/28/87 & 10/29/87	10/28/87		
18		10/30/87		
19		11/02/ 7		
20		11/03/87		

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
11	1117	1000	942	958	971	0	998	70.053	4.248	100.0	100.0
12	1120	845	1020	830	0	0	954	140.438	1.807	100.0	100.0
13	995	915	1015	995	0	0	980	44.347	6.314	100.0	100.0
14	830	915	890	955	0	0	898	52.361	3.772	100.0	100.0
15	800	645	865	820	0	0	783	95.612	0.863	78.8	88.0
16	820	900	890	920	0	0	883	43.493	4.196	100.0	100.0
17	1005	945	760	810	1030	1000	925	113.049	1.990	100.0	100.0
18	910	980	1030	890	0	0	953	64.485	3.916	100.0	100.0
19	760	855	770	790	0	0	794	42.696	2.196	100.0	100.0
20	795	710	865	740	0	0	778	68.130	1.138	87.9	98.4

APPENDIX P
PAP TEST RESULTS
WICHITA MID-CONTINENT AIRPORT

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FAA PAYMENT ADJUSTMENT DEFAULTS FOR AIRPORT PAVEMENT CONSTRUCTION
          P-501, Portland Cement Concrete Pavement
            for Wichita Mid-Continent Airport

*******************************************************************************

  1.  THE LOWEST PWL IN PERCENT TO RECEIVE 100% PAYMENT:  90

  2.  THE LOWEST PWL IN PERCENT TO RECEIVE MINIMUM PAYMENT:  60
      THE MINIMUM PAY FACTOR IN PERCENT TO RECEIVE PAYMENT:  50

  3.  THE MIDPOINT SCALING FACTOR BETWEEN [1] AND [-1]:  .6

*******************************************************************************

 PAY FACTOR FORMULA IS: -3.212007 *PWL^2 +  6.484677 *PWL + -2.234484

*******************************************************************************


              Press any key to return to program.
                  RESPONSE REQUEST MODE
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APPENDIX P (Continued)
PAP TEST RESULTS
WICHITA MID-CONTINENT AIRPORT

FAA ACCEPTANCE AND PAYMENT ADJUSTMENT FOR AIRPORT PAVEMENTS
P-501, Portland Cement Concrete Pavement

06-08-1990 PAGE 1

****

Airport: Wichita Mid-Continent Airport
Wichita, Kansas
ICT

Consultant/Engineer:

Construction Contractor:

Pavement Testing Laboratory: Professional Engineering Cons.
Wichita, Kansas

****

FAA Contract Number: AIP 3-20-088-09 & 10
FAA Project Name: Runway 1L-19R Reconstruction
Work Area Project Name: Runway 1L-19R Reconstruction - 28-days

****

Pavement Specification: P-501, Portland Cement Concrete Pavement
Design Target Specification in PSI: 650

****

Method of Testing: Flexural Beams
ASTM Number: ASTM C-78

****

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
1	7-25-1	07/25/87		28
2	7-27-1	07/27/87		28
3	7-27-1	07/27/87		28
4	7-30-1	07/30/87		28
5	7-30-1	07/30/87		28
6	7-30-3	07/30/87		28
7	7-30-3	07/30/87		28
8	8-01-1	08/01/87		28
9	8-01-1	08/01/87		28
10	8-01-3	08/01/87		28

****

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
1	777	777	766	869	0	0	797	48.114	3.060	100.0	100.0
2	823	766	849	853	0	0	823	40.103	4.308	100.0	100.0
3	762	747	781	781	0	0	768	16.480	7.145	100.0	100.0
4	702	763	708	648	0	0	705	47.013	1.175	89.2	99.4
5	761	829	669	791	0	0	763	68.262	1.648	100.0	100.0
6	706	734	701	744	0	0	721	20.998	3.393	100.0	100.0
7	771	650	750	696	0	0	717	54.573	1.223	90.8	100.0
8	780	710	752	725	0	0	742	30.859	2.973	100.0	100.0
9	743	752	729	749	0	0	743	10.210	9.133	100.0	100.0
10	684	760	682	663	0	0	697	42.890	1.102	86.7	97.3

APPENDIX P (Continued)
PAP TEST RESULTS
WICHITA MID-CONTINENT AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-08-1990 PAGE 2

Airport: Wichita Mid-Continent Airport, Wichita, Kansas
FAA Project Name: Runway 1L-19R Reconstruction
Work Area Project Name: Runway 1L-19R Reconstruction - 28-days

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
11	8-01-3	08/01/87		28
12	8-05-1	08/05/87		28
13	8-05-1	08/05/87		28
14	8-05-3	08/05/87		28
15	8-05-3	08/05/87		28
16	8-07-1	08/07/87		28
17	9-09-1	09/09/87		28
18	9-09-1	09/09/87		28
19	9-10-2	09/10/87		28
20	9-10-2	09/10/87		28
21	9-10-4	09/10/87		28
22	9-10-4	09/10/87		28
23	9-13-2	09/13/87		28
24	9-13-2	09/13/87		28
25	9-13-4	09/13/87		28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
11	723	672	710	710	0	0	704	22.036	2.439	100.0	100.0
12	749	725	735	715	0	0	731	14.514	5.581	100.0	100.0
13	698	713	725	780	0	0	729	35.749	2.210	100.0	100.0
14	785	810	685	695	0	0	744	63.031	1.487	99.6	100.0
15	723	674	556	576	0	0	632	79.492	-0.223	42.6	0.0
16	830	775	616	677	0	0	725	96.106	0.775	75.8	83.6
17	696	813	725	794	0	0	757	55.528	1.927	100.0	100.0
18	710	661	706	764	0	0	710	42.161	1.429	97.6	100.0
19	616	657	601	682	0	0	639	37.175	-0.296	40.1	0.0
20	641	631	680	695	0	0	662	30.631	0.384	62.8	57.1
21	691	676	757	713	0	0	709	35.274	1.680	100.0	100.0
22	804	779	770	760	0	0	778	18.839	6.808	100.0	100.0
23	760	660	795	805	0	0	755	66.207	1.586	100.0	100.0
24	672	747	617	694	0	0	683	53.830	0.604	70.1	73.3
25	836	796	742	783	0	0	789	38.742	3.594	100.0	100.0

APPENDIX P (Continued)
PAP TEST RESULTS
WICHITA MID-CONTINENT AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-08-1990 PAGE 3

Airport: Wichita Mid-Continent Airport, Wichita, Kansas
FAA Project Name: Runway 1L-19R Reconstruction
Work Area Project Name: Runway 1L-19R Reconstruction - 28-days

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
26	9-13-4	09/13/87		28
27	9-17-2	09/17/87		28
28	9-17-2	09/17/87		28
29	9-17-4	09/17/87		28
30	9-17-4	09/17/87		28
31	9-26-1	09/26/87		28
32	9-26-1	09/26/87		28
33	9-26-2	09/26/87		28
34	9-26-2	09/26/87		28
35	9-30-2	09/30/87		28
36	9-30-2	09/30/87		28
37	9-30-4	09/30/87		28
38	9-30-4	09/30/87		28
39	10-1-2	10/01/87		28
40	10-1-2	10/01/87		28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
26	793	830	840	800	0	0	816	22.780	7.276	100.0	100.0
27	720	700	823	737	0	0	745	54.154	1.754	100.0	100.0
28	711	654	702	707	0	0	694	26.589	1.636	100.0	100.0
29	813	727	702	717	0	0	740	49.902	1.799	100.0	100.0
30	793	712	760	850	0	0	779	57.985	2.220	100.0	100.0
31	613	721	667	621	0	0	656	49.729	0.111	53.7	0.0
32	636	682	714	678	0	0	678	32.016	0.859	78.6	87.9
33	727	722	678	704	0	0	708	22.157	2.606	100.0	100.0
34	719	709	651	646	0	0	681	38.091	0.820	77.3	86.0
35	699	765	648	750	0	0	716	53.132	1.233	91.1	100.0
36	725	774	735	675	0	0	727	40.746	1.896	100.0	100.0
37	752	798	724	836	0	0	778	49.514	2.575	100.0	100.0
38	879	934	869	727	0	0	852	88.255	2.292	100.0	100.0
39	808	769	725	755	0	0	764	34.461	3.315	100.0	100.0
40	779	853	921	872	0	0	856	58.931	3.500	100.0	100.0

APPENDIX P (Continued)
PAP TEST RESULTS
WICHITA MID-CONTINENT AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-08-1990 PAGE 4

Airport: Wichita Mid-Continent Airport, Wichita, Kansas
FAA Project Name: Runway 1L-19R Reconstruction
Work Area Project Name: Runway 1L-19R Reconstruction - 28-days

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
41	10-1-4	10/01/87		28
42	10-1-4	10/01/87		28
43	10-2-2	10/02/87		28
44	10-2-2	10/02/87		28
45	10-3-1	10/03/87		28
46	10-3-1	10/03/87		28
47	10-6-2	10/06/87		28
48	10-6-2	10/06/87		28
49	10-6-4	10/06/87		28
50	10-6-4	10/06/87		28
51	10-7-5	10/07/87		28
52	10-7-5	10/07/87		28
53	10-9-1	10/09/87		28
54	10-9-1	10/09/87		28
55	10-9-3	10/09/87		28

LOT NO.	TEST RESULT STRENGTH IN PSI # 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
41	862	808	867	872	0	0	852	29.781	6.791	100.0	100.0
42	862	789	835	905	0	0	848	48.630	4.066	100.0	100.0
43	873	897	810	795	0	0	844	49.013	3.953	100.0	100.0
44	784	911	745	821	0	0	815	70.976	2.328	100.0	100.0
45	825	790	770	755	0	0	785	30.277	4.459	100.0	100.0
46	793	828	852	831	0	0	826	24.454	7.197	100.0	100.0
47	843	887	838	828	0	0	849	26.090	7.628	100.0	100.0
48	838	867	938	959	0	0	901	57.321	4.370	100.0	100.0
49	867	765	791	816	0	0	810	43.477	3.674	100.0	100.0
50	842	755	768	803	0	0	792	39.013	3.640	100.0	100.0
51	865	875	843	955	0	0	885	48.864	4.799	100.0	100.0
52	969	944	840	810	0	0	891	77.577	3.103	100.0	100.0
53	880	895	740	845	0	0	840	69.881	2.719	100.0	100.0
54	857	867	855	680	0	0	815	89.987	1.831	100.0	100.0
55	755	877	808	1005	0	0	861	108.069	1.955	100.0	100.0

APPENDIX P (Continued)
PAP TEST RESULTS
WICHITA MID-CONTINENT AIRPORT

FAA PAYMENT ADJUSTMENT (CONTINUED)
P-501, Portland Cement Concrete Pavement

06-08-1990 PAGE 5

Airport: Wichita Mid-Continent Airport, Wichita, Kansas
FAA Project Name: Runway 1L-19R Reconstruction
Work Area Project Name: Runway 1L-19R Reconstruction - 28-days

LOT NO.	SAMPLE LOCATION	SAMPLE DATE	TEST DATE	AGE OF SAMPLE
56	10-9-3	10/09/87		28
57	10-12-2	10/12/87		28
58	10-12-2	10/12/87		28
59	10-12-4	10/12/87		28
60	10-12-4	10/12/87		28
61	10-21-1	10/21/87		28
62	10-21-1	10/21/87		28
63	10-22-2	10/22/87		28
64	10-22-5	10/22/87		28
65	10-22-5	10/22/87		28

LOT NO.	# 1	# 2	# 3	# 4	# 5	# 6	AVERAGE	STD DEV	EST QL	EST PWL	% PAY FACTOR
	-------TEST RESULT STRENGTH IN PSI--------										
56	833	892	876	851	0	0	863	26.166	8.140	100.0	100.0
57	734	755	834	816	0	0	785	47.829	2.817	100.0	100.0
58	790	740	888	0	0	0	806	75.286	2.072	100.0	100.0
59	999	892	735	855	0	0	870	108.896	2.023	100.0	100.0
60	775	775	925	865	0	0	835	73.485	2.518	100.0	100.0
61	900	960	725	830	0	0	854	100.943	2.018	100.0	100.0
62	965	885	867	928	0	0	911	44.033	5.933	100.0	100.0
63	887	887	926	833	877	813	871	40.938	5.386	100.0	100.0
64	1122	1000	806	842	0	0	943	146.355	1.999	100.0	100.0
65	965	838	942	927	0	0	918	55.576	4.822	100.0	100.0